FUJITSU SEMICONDUCTOR
CONTROLLER MANUAL

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FM3 Family

µT-Kernel Specification Compliant

µT-REALOS/M3 for RVDS USER'S GUIDE

FM3 Family

µT-Kernel Specification Compliant

µT-REALOS/M3 for RVDS USER'S GUIDE

µT-Kernel

FUJITSU SEMICONDUCTOR LIMITED

Preface

■ Purpose and Intended Reader of This Manual

This manual is intended to be read by those who create application programs using µT-REALOS/M3 for RVDS (referred to as "µT-REALOS" hereafter), and describes the overall functionality of µT-REALOS, how to create application programs, and the procedure for building a system.

µT-REALOS is a µT-Kernel specification real-time OS that runs on the Fujitsu microcontroller FM3 Family (referred to as "FM3" hereafter). FM3 adopts ARM Cortex-M3 core.

Reading this manual requires basic knowledge of the Cortex-M3 architecture and µT-Kernel, which is available from the following documents.

- "Cortex-M3 Technical Reference Manual" (the architecture of FM3)
- "µT-Kernel Specification" (the specification of µT-Kernel)

See the following document for details on the system call interfaces.

- "µT-REALOS/M3 API Reference" (referred to as "API Reference" hereafter)

■ About the µT-Kernel

The µT-Kernel specifications are specifications for an open real-time OS established by the T-Engine Forum. The µT-Kernel specifications are available from the T-Engine Forum website (http://www.t-engine.org/). The original copyright for the µT-Kernel belongs to Mr. Ken Sakamura. The copyright for the µT-Kernel specifications belongs to the T-Engine Forum. This product uses the µT-Kernel source code from the T-Engine Forum (www.t-engine.org) based on the µT-License.

■ Trademarks

■ Overall Structure of This Manual

This manual consists of five chapters and an appendix as follows.

CHAPTER 1 OVERVIEW OF μT-REALOS

This chapter explains an overview of μT-REALOS. μT-REALOS is a μT-Kernel specification real-time OS that runs on the FM3 family. μT-REALOS is conforms to the μT-Kernel specifications.

CHAPTER 2 BASIC CONCEPTS OF THE μT-REALOS KERNEL

This chapter explains the basic concepts that are required to understand the μT-REALOS kernel.

CHAPTER 3 μT-REALOS FUNCTIONS

This chapter explains the functions supported by μT-REALOS.

CHAPTER 4 WRITING A USER PROGRAM

This chapter describes the basic items in writing a user program on μT-REALOS.

CHAPTER 5 HOW TO CONSTRUCT A SYSTEM

This chapter explains how to construct a user system.

APPENDIX

The appendix explains error messages of the configurator.

■ Reference Manuals

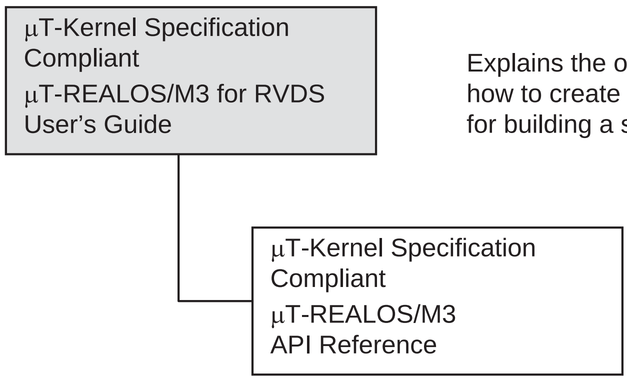
See the manuals listed below as required while using this system.

- "Cortex-M3 Technical Reference Manual"
- "μT-Kernel Specification"
- "μT-REALOS/M3 API Reference"

■ Organization of the μT-REALOS Manuals

The μT-REALOS manuals are divided into the following three volumes.

First-time users of μT-REALOS should read the "μT-REALOS/M3 User's Guide" first.


μT-Kernel Specification Compliant
μT-REALOS/M3 for RVDS User's Guide
μT-Kernel Specification Compliant
μT-REALOS/M3 API Reference

Explains the overall functionality of μT-REALOS, how to create application programs, and the procedure for building a system. (This document)

Explains the details of the μT-REALOS API.

■ How to read This Manual

● Explanation of terminology

The terminology used in this manual is described below.

Word	Overview
Kernel	The program that provides the OS functionality is called the kernel.
User program	Refers to application programs that use µT-REALOS functions. In order to emphasize the point that these programs are created by the user, these are called user programs in this manual.
User system	Refers to an executable program formed by linking a user program with µT-REALOS.
System call	The group of functions that implement OS functionality and that can be called directly from a user program are called system calls.
Object	The resources that are handled by the kernel are called objects. Specifically, this refers to semaphores, mailboxes, and other objects that implement functionality such as tasks, synchronization, and communications.
Configuration definition macros	The configuration definition macros are written in the system configuration file, and act as an interface for setting kernel configuration parameters.
Idle state	The state when there are no tasks ready to execute.

This manual is made based on the specification of μ-Kernel with the formal agreement by the T-Engine Forum.

CONTENTS

CHAPTER 1 OVERVIEW OF μT-REALOS

This chapter explains an overview of μT-REALOS.
μT-REALOS is a μT-Kernel specification real-time OS that runs on the FM3 family.
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1.1 Supported Functions

This section explains the supported functions of µT-REALOS.

■ Supported Functions

µT-REALOS supports the functions listed below.

For details on the functions, see "CHAPTER 3 µT-REALOS FUNCTIONS" herein and "CHAPTER 3 SYSTEM CALL INTERFACE" in "API Reference".

- Task management functions
- Task synchronization functions
- Synchronization and communication functions (semaphores, event flags, mailboxes)
- Extended synchronization and communication functions (mutexes, message buffers, rendezvous ports)
- Memory pool management functions (fixed length memory pool, variable length memory pool)
- Time management functions
- Interrupt management functions
- System configuration management functions
- Subsystem management functions
- Device management functions
- Power saving functions

The following development tools are also provided with µT-REALOS for use when building or debugging a system. These are Windows applications that run on a PC.

- µT-REALOS Configurator

µT-REALOS Configurator (referred to as the "Configurator" in this manual) is used when building a user system to configure the kernel based an a predefined structure. See "3.13 Kernel Configuration Function" for details on the Configurator functions.

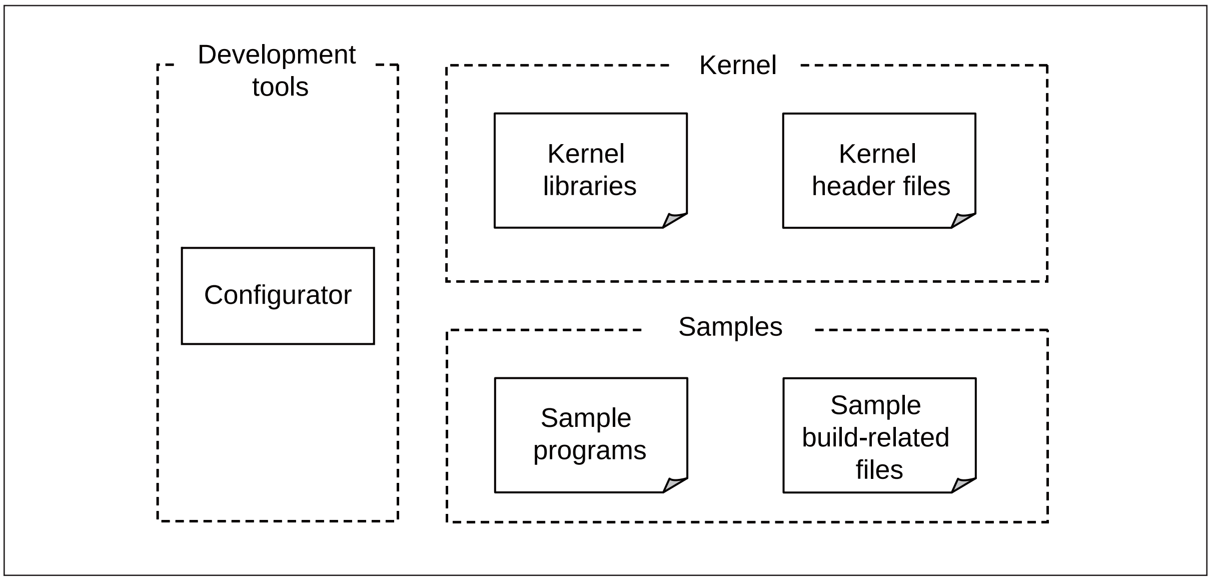
1.2 Structure of Product

This section explains the structure of the product.

■ Structure of Product

The structure of µT-REALOS is shown below.

Figure 1.2-1 Structure of µT-REALOS



- Configurator

  The Configurator modules that run under Windows. They are command format (.exe) executable files that are run from the command prompt window.

- Kernel libraries

  The µT-REALOS kernel object files are included in the library format.

- Kernel header files

  Header files that are included by user programs, and which define system calls and parameter types.

- Sample programs

  Samples programs of reset entry routines, initialization processing, timer interrupt handlers, and tasks.

- Sample build-related files

  These are project files, configuration files, and other files for the sample programs.

1.3 Tools Required for Development

This section explains the tools that are required to develop a user system.

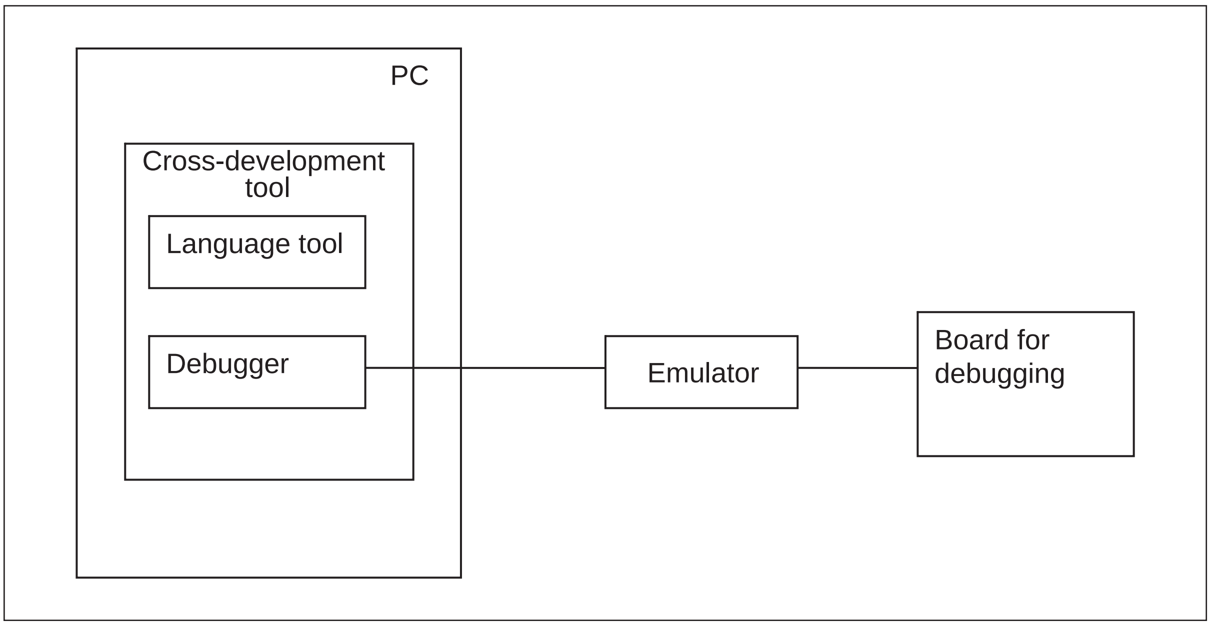
■ Tools Required for Development

The following tools are required to develop a µT-REALOS user system.

- Cross-development tool
  ARM's RealView Development Suite (RVDS)
- Emulator
  ARM's RealView ICE (RVI)

For details on the tool version, see Release Notes.

Figure 1.3-1 Structure of Development Tools



CHAPTER 2 BASIC CONCEPTS OF THE μT-REALOS KERNEL

This chapter explains the basic concepts that are required to understand the μT-REALOS kernel.

2.1 System Calls

This section explains the system calls which act as interfaces for using kernel functions from the user program.

■ System Calls

The interfaces for calling kernel functions from a user program are called system calls. The system calls conform to the μT-Kernel specifications.

See "CHAPTER 3 SYSTEM CALL INTERFACE" of the "API Reference" for details on the system calls.

2.2 Execution Units of User Program

This section explains the execution units of a user program.

■ Execution Units of User Program

The execution units of a user program are listed below:

- Tasks
- Initialization routines
- Interrupt handlers
- Time event handlers
- Error routines
- Extended SVC handlers
- Device processing functions

2.2.1 Tasks

This section explains tasks.

■ Tasks

Tasks are the program execution unit that form the basis of user program processing.

µT-REALOS saves the state prior to the interrupt (register values) on a per-task basis if the execution of a task is interrupted. This is called the task context. The information saved in the task context can be used to resume execution of the interrupted task.

Tasks have a variety of states, including the run state, ready state, wait state, etc. See "■Task Portion Transitions" for details on the task portion transitions.

■ Invoking Task and Other Tasks

When a system call is made from a task, the calling task is called the invoking task and all other tasks are called other tasks.

■ Precedence and Task Priorities

The order of execution of program execution units is called the precedence. The value that determines the precedence of a task is called the task priority. The smaller the value of the task priority, the higher the priority. Tasks with a higher priority (small task priority value) have precedence when executing.

The task priority consists of a base priority, current priority, and startup priority. The term task priority by itself refers to the current priority.

● Current priority

The current priority is used to determine the execution sequence of the task.

● Base priority

The base priority is the base priority of the task, and normally has the same value as the current priority. When mutex functions are used, however, the current priority may be changed temporarily in some cases and can differ from the base priority. Even in these situations, however, the modified current priority is restored to the base priority when the mutex function has finished being used (see "3.5.1 Mutex Functions").

● Startup priority

The startup priority is the priority specified when a task is created, and the base priority of the task is initialized to the value of the startup priority when the task starts.

■ Dispatching and Preemption

The process of switching between running tasks is called dispatching. The process of a task that is in the run state losing the execution right is called preemption. The functionality within the kernel that implements dispatching is called the dispatcher.

Dispatching occurs when a task that has a higher priority than the currently executing task enters the ready state. Preemption occurs when a dispatch occurs or an interrupt handler is activated while a task is executing.

■ Task Portions

Tasks have the following states.

● RUNNING

The state where the task is running.

However, if a non-task portion is being executed, the task executed prior to the non-task portion is executed.

● READY

The state where the task is ready to execute, but is unable to run because a task that is higher in the precedence is currently running.

● WAITING

The state where execution has been suspended due to calling a system call with some kind of wait condition. This is categorized into the following states depending on the wait condition.

- Wakeup wait state (waiting due to tk_slp_tsk)
- Elapsed time wait state (waiting due to tk_dly_tsk)
- Semaphore resource acquisition wait state (waiting due to tk_wai_sem)
- Event flag wait state (waiting due to tk_wai_flg)
- Receive from mailbox wait state (waiting due to tk_rcv_mbx)
- Mutex lock wait state (waiting due to tk_loc_mtx)
- Send to message buffer wait state (waiting due to tk_snd_mbf)
- Receive from message buffer wait state (waiting due to tk_rcv_mbf)
- Fixed length memory block acquisition wait state (waiting due to tk_get_mpf)
- Variable length memory block acquisition wait state (waiting due to tk_get_mpl)
- Rendezvous call/termination wait state (waiting due to tk_cal_por)
- Rendezvous accept wait state (waiting due to tk_acp_por)

● SUSPENDED

The state where execution has been forcefully suspended by another task.

● WAITING-SUSPENDED

This state is both WAITING and SUSPENDED at the same time.

● DORMANT

The state where the task has not yet been started, or the task has ended.

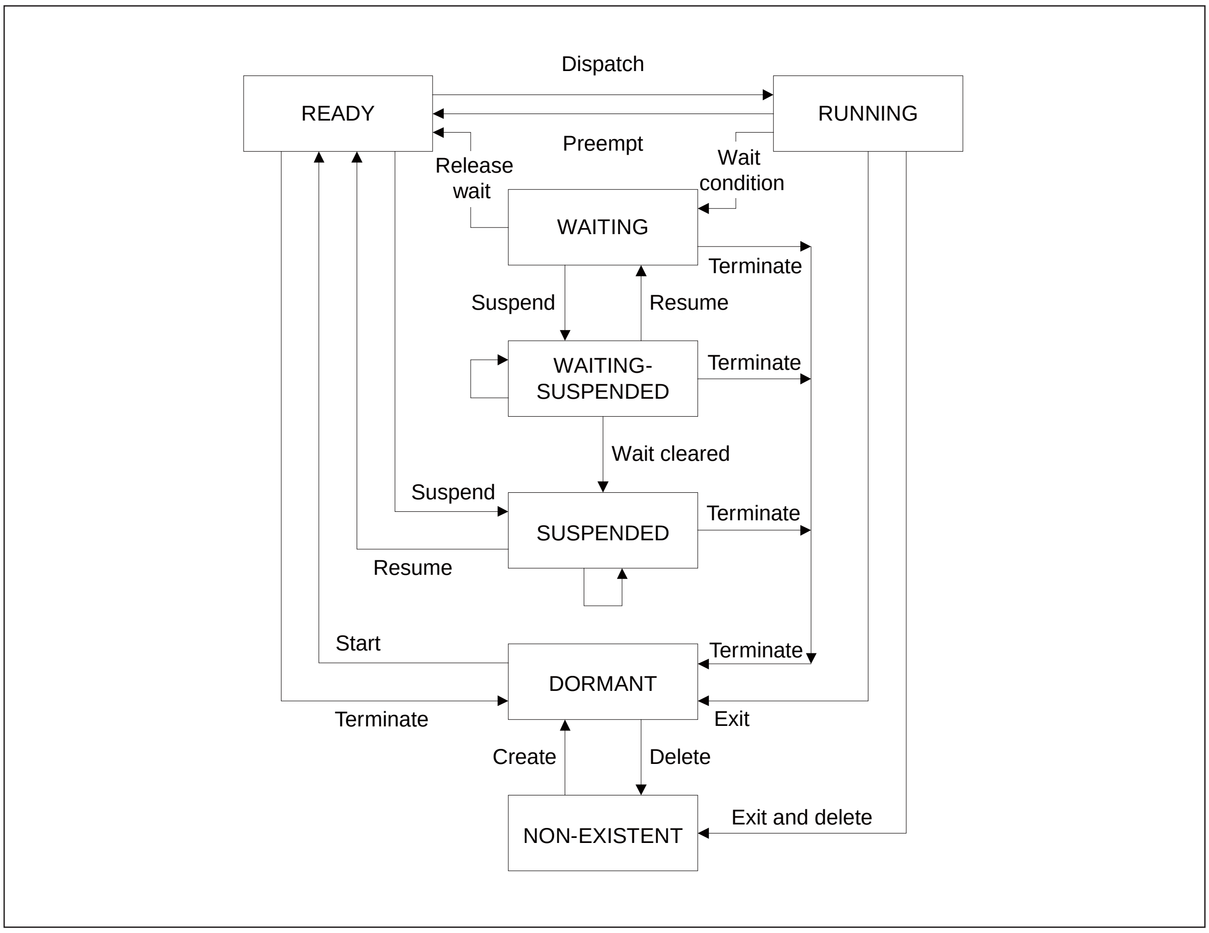
● NON-EXISTENT

The state where the task has not yet been created, or the task has been deleted.

■ Task Portion Transitions

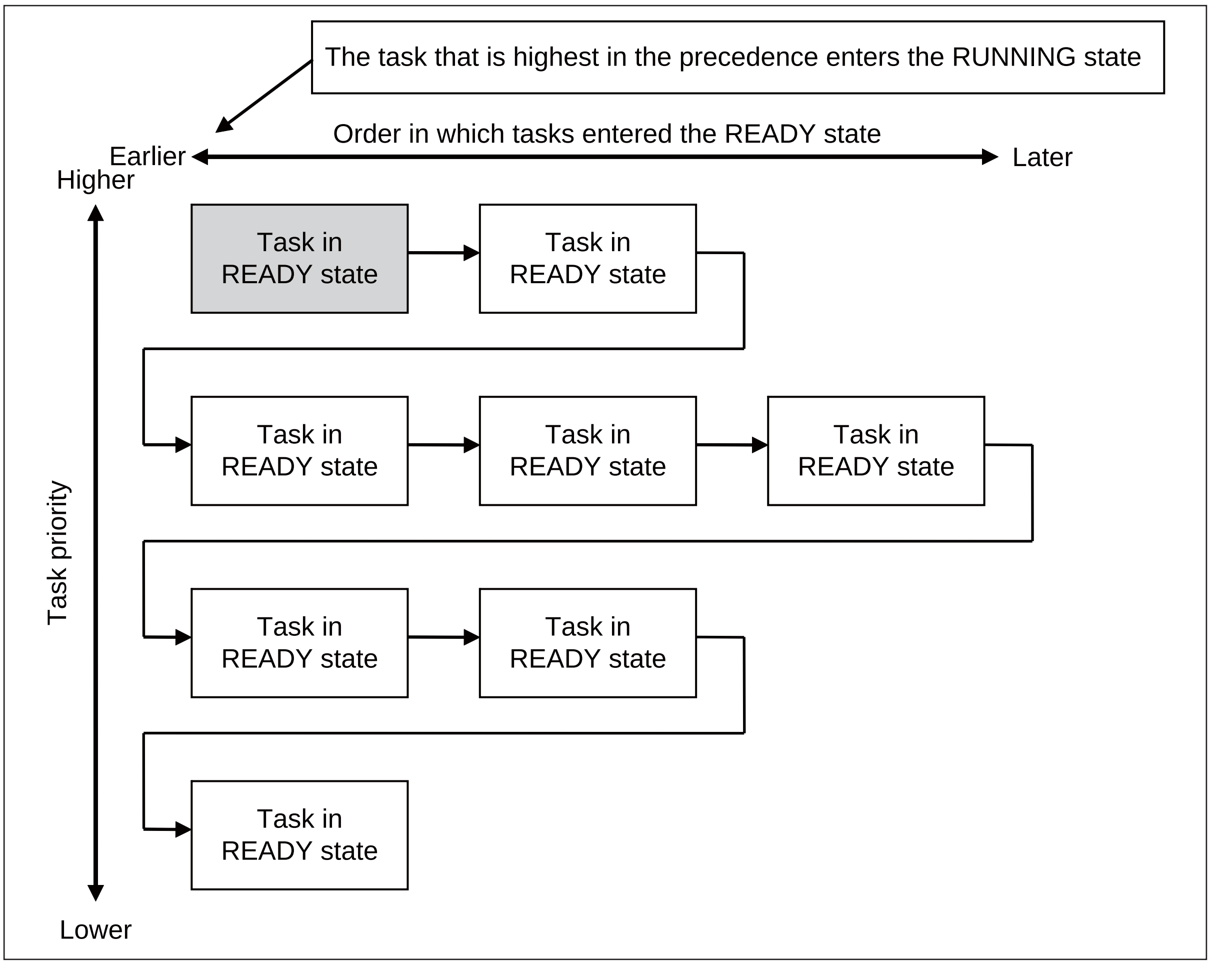
The state transitions for tasks are shown below.

Figure 2.2-1 Task Portion Transitions



Multiple ready state tasks are scheduled (controlling execution order) according to task precedence. Higher precedence is given to tasks with higher task priority. For tasks with the same task priority, higher precedence is given to the task that is transitioned into ready state first.

Figure 2.2-2 Conceptual Diagram of the Precedence



The running task continues the execution until it enters the READY state after the priority order is changed or it enters another state (WAITING state, SUSPENDED state, WAITING-SUSPENDED state, DORMANT state, NON-EXISTENT state). At that time, the task in another READY state is not executed.

2.2.2 Initialization Routines

This section explains initialization routines.

■ Initialization Routines

Initialization routines are programs using initialization processes that are unique to the user program. In general, the user program prepares the operating environment by creating tasks and semaphore objects, and by registrating interrupt handlers and devices.

At the startup of the kernel, one task is created (this task is called an initial task), and an initialization routine is called from this task. An initialization routine therefore runs on a task.

2.2.3 Interrupt Handlers

This section explains interrupt handlers.

■ Interrupt Handlers

An interrupt handler is a program that is activated synchronously with peripheral hardware interrupt sources, system exceptions, and software interrupt instructions. Interrupt handlers can be defined for each interrupt source.

If an interrupt occurs while a task is running, the kernel temporarily interrupts task execution and runs the interrupt handler corresponding to the interrupt source that occurred. At this time, the stack switches to the stack that is provided for executing interrupt processing (the system stack). The interrupt handler therefore does not execute in the context of the task that had been running, but instead executes in an independent context.

Furthermore, all of the interrupt handlers run at a higher priority than the tasks, therefore tasks do not run until the interrupt handler has finished. If multiple interrupt handlers are activated, task execution does not continue until all of the interrupt handlers have finished processing. Therefore, even if an interrupt handler calls a system call that results in a dispatch (such as starting a task with a high priority), the actual task dispatch is not performed until after all of the interrupt handlers have finished processing. This behavior is called "delayed dispatching".

See "3.8 Interrupt Management Functions" for details on the interrupt handlers.

2.2.4 Time Event Handlers

This section explains time event handlers.

■ Time Event Handlers

Cyclic handlers and alarm handlers are collectively referred to as time event handlers.

■ Cyclic Handlers

A cyclic handler is a program that is activated at a specified interval regular. Programs that are executed periodically can be defined as cyclic handlers, and the execution and suspension of these handlers are able to be controlled.

If the specified interval elapses while a task is executing, the task execution is temporarily interrupted and the corresponding cyclic handler is activated. The cyclic handler does not execute in the context of the task that had been running, but instead executes in an independent context.

Furthermore, all of the cyclic handlers run at a higher priority than the tasks, therefore tasks do not run until the cyclic handler has finished. Even if the cyclic handler calls a system call that results in a dispatch (such as starting a task with a high priority), the actual task dispatch is not performed until after the cyclic handler has finished processing.

The cyclic handlers in µT-REALOS are activated from within isig_tim, which is called from the timer interrupt handler for the system clock. The cyclic handlers therefore operate as part of the timer interrupt handler. Time-related handlers that are activated from the timer interrupt handler in this way are called "time event handlers". As described earlier, cyclic handlers execute as part of the timer interrupt handler, and a cyclic handler is therefore not interrupted to process other time event handlers while the cyclic handler is running.

The time when a cyclic handler is first activated is calculated based on the time tick following the time when the cyclic handler is created or activated. However, if a cyclic handler is created or activated from within a time event handler, the time is calculated based on the time when the time event handler was activated. The activation time after the first time is calculated based on the time when the cyclic handler was activated.

● Activation Phase

The relative time until the cyclic handler is first activated, based on the time of the system call that creates the cyclic handler.

● Activation Interval

The relative time until the next cyclic handler is activated, based on the time when the cyclic handler should have been activated (not when it was activated).

See "3.7.2 Cyclic Handler Functions" for details on cyclic handlers.

■ Alarm Handlers

An alarm handler is a program that is activated at a specified time. The program that is executed at the specified time is created as an alarm handler, and the execution and suspension of these handlers are able to be controlled.

If the specified time is reached while a task is executing, the task execution is temporarily interrupted and the corresponding alarm handler is executed. The alarm handler does not execute in the context of the task that had been running, but instead executes in an independent context.

Furthermore, all of the alarm handlers run at a higher priority than the tasks, therefore tasks do not run until the alarm handler has finished. Even if the alarm handler calls a system call that results in a dispatch (such as starting a task with a high priority), the actual task dispatch is not performed until after the alarm handler has finished processing.

The alarm handlers in µT-REALOS operate as part of the interrupt handler for the system clock. Alarm handlers are therefore not interrupted to process other time event handlers while the alarm handler is running.

The time when the alarm handler is activated is calculated based on the time tick following the time when the alarm handler is activated. However, if an alarm handler is activated from within a time event handler, the time is calculated based on the time when the time event handler was activated.

See "3.7.3 Alarm Handler Functions" for details on alarm handlers.

2.2.5 Error Routines

This section explains error routines.

■ Error Routines

An error routine is a program that is run when the kernel detects some kind of error.

The error routine is activated under the following conditions.

- System Down

  An internal kernel inconsistency is detected
- Initial Settings Error

  An error occurs during kernel initialization
- Undefined Interrupt

  An interrupt occurs that does not have a defined interrupt handler

The error routine is used for the purpose of debugging the user program. There is no way to recover from the error routine. Therefore, if the error routine has been called, clear the cause of the error and restart the system.

If an error routine is called in the initial setting error, it is executed as a task portion. Otherwise, it is executed as a task-independent portion. For details on task portions and task-independent portions, see "2.4 System States".

2.2.6 Extended SVC Handlers

This section explains extended SVC handlers.

■ Extended SVC Handlers

An extended SVC handler is a handler that accepts request for subsystem. When called from a task portion, it is executed as a quasi-task portion. When called from a task-independent portion, it is executed as a task-independent portion. For details on subsystems, refer to "3.10 Subsystem Management Functions", and for details on quasi-task portions, refer to "2.4 System States".

2.2.7 Device Processing Functions

This section explains the device processing functions.

■ Device Processing Functions

A device processing function is used when a device driver function is called by a device management function. If a device processing function is called by a task portion, it is executed as a task portion. If it is called by a task-independent portion, it is executed as a task-independent portion. For details on device processing functions, refer to "3.11 Device Management Functions".

2.3 Objects

This section explains objects.

■ Objects

μT-REALOS supports a variety of functions, including synchronization/communication between tasks, exclusive control, and acquisition/release of memory regions. The resources that operate on system calls in order to use these functions from a user program are called objects.

The following objects are supported by μT-REALOS.

Table 2.3-1 List of Objects

Object	Synopsis
Task	The task is object in the most fundamental unit that makes up a user program.
Semaphore	Semaphores are objects for representing numerically the number and availability of unused resources, and for managing exclusive control and synchronization when using those resources.
Event flag	Event flags are objects that perform synchronization by representing the presence or absence of events as bit flags.
Mailboxes	Mailboxes are objects that perform synchronization and communication by receiving messages that are stored in memory.
Mutexes	Mutexes are objects that perform exclusive access control between tasks that use a shared resource.
Message buffers	Message buffers are objects that perform synchronization and communication by receiving variable-length messages.
Rendezvous ports	Rendezvous ports provide intertask synchronous communication functionality, and support a single sequence where one task requests processing of another task and the second task then returns the processing result to the first task. The object that synchronizes the waiting of both tasks is called a rendezvous port.
Fixed-size memory pool	Fixed-size memory pool are objects for dynamically managing fixed size memory blocks.
Variable-size memory pool	Variable-size memory pool are objects for dynamically managing arbitrary size memory blocks.
Cyclic handlers	Cyclic handlers are time event handlers that activate at a fixed period.
Alarm handlers	Alarm handlers are time event handlers that activate at a specified time.

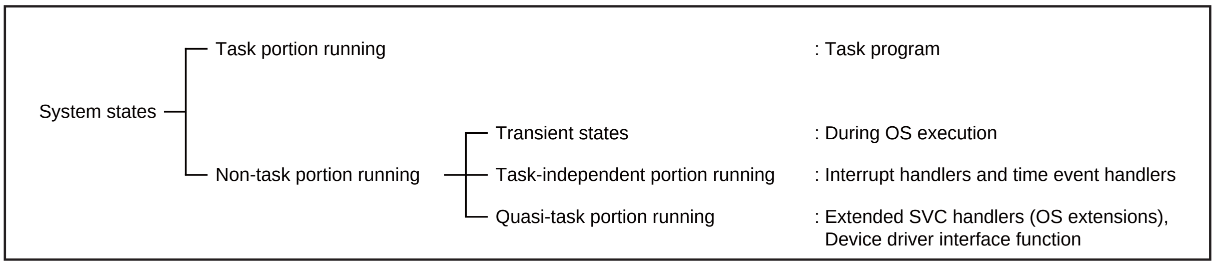
2.4 System States

This section explains the system states.

■ System States

The system states of µT-REALOS are divided into the following categories.

Figure 2.4-1 System States


System states
Task portion running
: Task program
Non-task portion running
Transient states
: During OS execution
Task-independent portion running
: Interrupt handlers and time event handlers
Quasi-task portion running
: Extended SVC handlers (OS extensions), Device driver interface function

■ Task Portion Running

"Task portion running" are the states in which task programs run. This does not include states in which the OS (system calls) executes or states in which handlers execute, which are part of the "Non-task portion running" described below.

■ Non-task Portion Running

"Non-task portion running" are further subdivided into the three states of "transient states", "task-independent portion running", and "quasi-task portion running".

(1) "Transient States"

"Transient States" refer to the states in which µT-REALOS system call processing is executed.

(2) "Task-indePendent Portion Running", "Quasi-task Portion Running"

"Task-independent Portion Running" refer to the states in which interrupt handlers and time event handlers are executed.

"Quasi-task Portion Running" refer to the states in which extended SVC handlers and device driver interface functions are executed.

■ System Calls that can be called

Except for system calls such as tk_ret_int and isig_tim that are required to be called from a "task-independent portion", all of the system calls can be called from the "task portions" and "quasi-task portions".

In contrast, "task-independent portions" execute in a context that is independent of any tasks, and do not have the concept of a task. The following system calls therefore cannot be called from the task-independent portions.

- System calls that explicitly specify the invoking task (calls where tskid is specified using the "TSK_SELF" macro)
- System calls that implicitly specify the invoking task (calls that enter a WAITING)

See Section "3.1 List of System Calls" of the "API Reference" for details on the system calls that can be called from each of the system states.

■ User Programs and System States

Table 2.4-1 shows the relationship between the parts of a user program and the system states.

Table 2.4-1 System States of Each Part of a User Program

User Program Component	System State
Tasks	Task portion
Extended SVC handlers	Non-task portion (quasi-task portion, task-independent portion)
Device drivers	Non-task portion (quasi-task portion)
Cyclic handlers	Non-task portion (task-independent portion)
Alarm handlers	Non-task portion (task-independent portion)
Interrupt handlers	Non-task portion (task-independent portion)
Error routines	Task portion, non-task portion (task-independent portion)

Note:

The µT-Kernel specifications do not define isig_tim and error routines. These are extended functionality that is specific to µT-REALOS.

2.5 Dispatch and Interrupts Enabled/disabled States

This section explains the dispatch enabled/disabled states and the interrupts enabled/disabled states.

■ Dispatch Enabled/disabled States

During execution of a user program, the dispatcher is either in the dispatch disabled state or the dispatch enabled state. After system initialization, the dispatcher is in the dispatch enabled state when the initial task begins executing.

In the dispatch disabled state, the system does not switch the task that is in the RUNNING. While in the dispatch disabled state, an error (E_CTX) occurs if a system call is made where there is a possibility of the currently running task entering the WAITING. However, interrupt handlers, cyclic handlers, and alarm handlers remain active.

The dispatch disabled/enabled states can be controlled from a user program by calling the following system calls.

- tk_dis_dsp: Enters the dispatch disabled state
- tk_ena_dsp: Enters the dispatch enabled state

■ Interrupts Enabled/disabled States

During execution of a user program, the system is either in the interrupts disabled state or the interrupts enabled state. After system initialization, the system is in the interrupts enabled state when the initial task begins executing.

In the interrupts disabled state, all external interrupts are disabled such that control is not passed to an interrupt handler even if a hardware interrupt occurs.

Furthermore, if dispatching is also disabled, then the system does not switch from the currently running task. While in the interrupts disabled state, an error (E_CTX) occurs if a system call is made where there is a possibility of the currently running task entering the WAITING. An error (E_CTX) also occurs if a system call is made to enable or disable dispatching (tk_dis_dsp or tk_ena_dsp) while in the interrupts disabled state.

The interrupts enabled/disabled states can be controlled from a user program by calling the following macros.

- DI: Enters the interrupts disabled state
- EI: Enters the interrupts enabled state

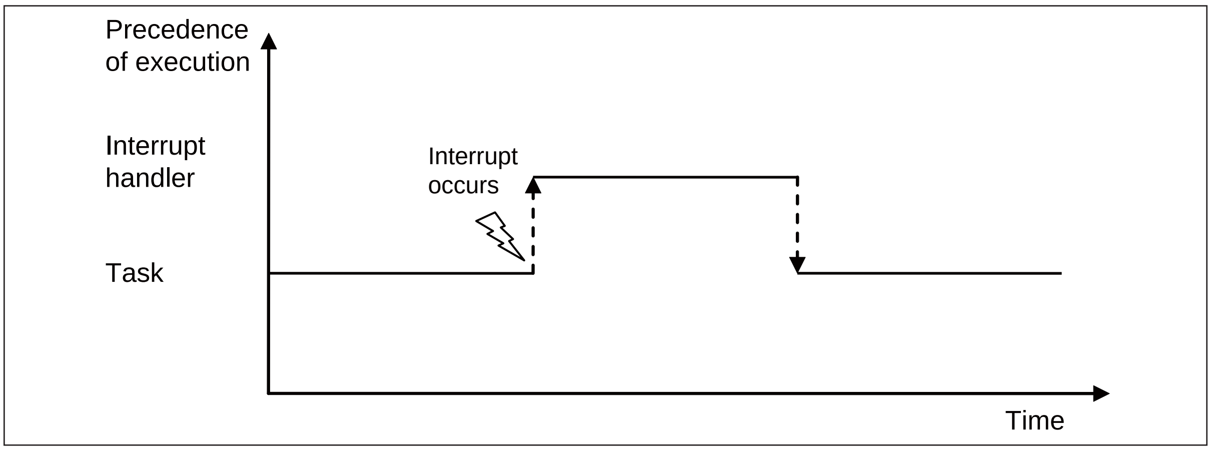
2.6 Precedence of Execution of Tasks and Handlers

This section explains the precedence of execution of tasks and handlers.

■ Precedence of Execution (Tasks vs. Interrupt Handlers and Time Event Handlers)

Handlers have a higher precedence of execution than tasks. For example, if a hardware interrupt occurs while a task is executing, the execution of the task is suspended and the interrupt handler corresponding to the interrupt is executed. When the interrupt handler finishes executing, the task resumes execution from the point where it was suspended.

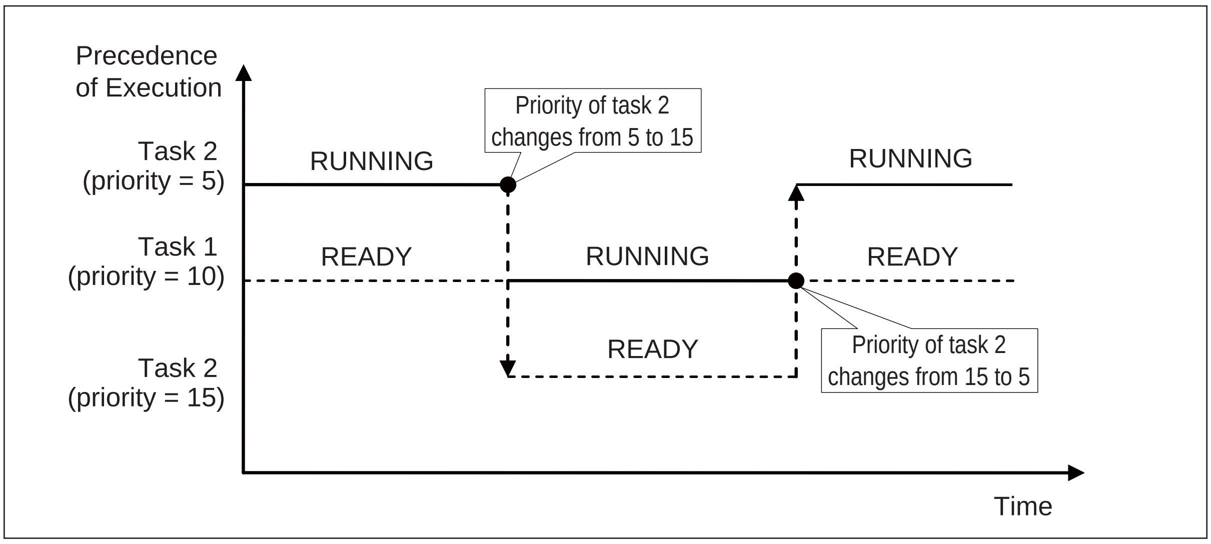
Figure 2.6-1 Precedence of Execution (Tasks vs. Interrupt Handlers and Time Event Handlers)



■ Precedence of Execution (Tasks vs. Tasks)

The precedence of execution of tasks executes tasks that have a higher priority first. If a task with a higher priority than the task that is currently executing enters the READY, the currently executing task is suspended and the higher priority task is executed.

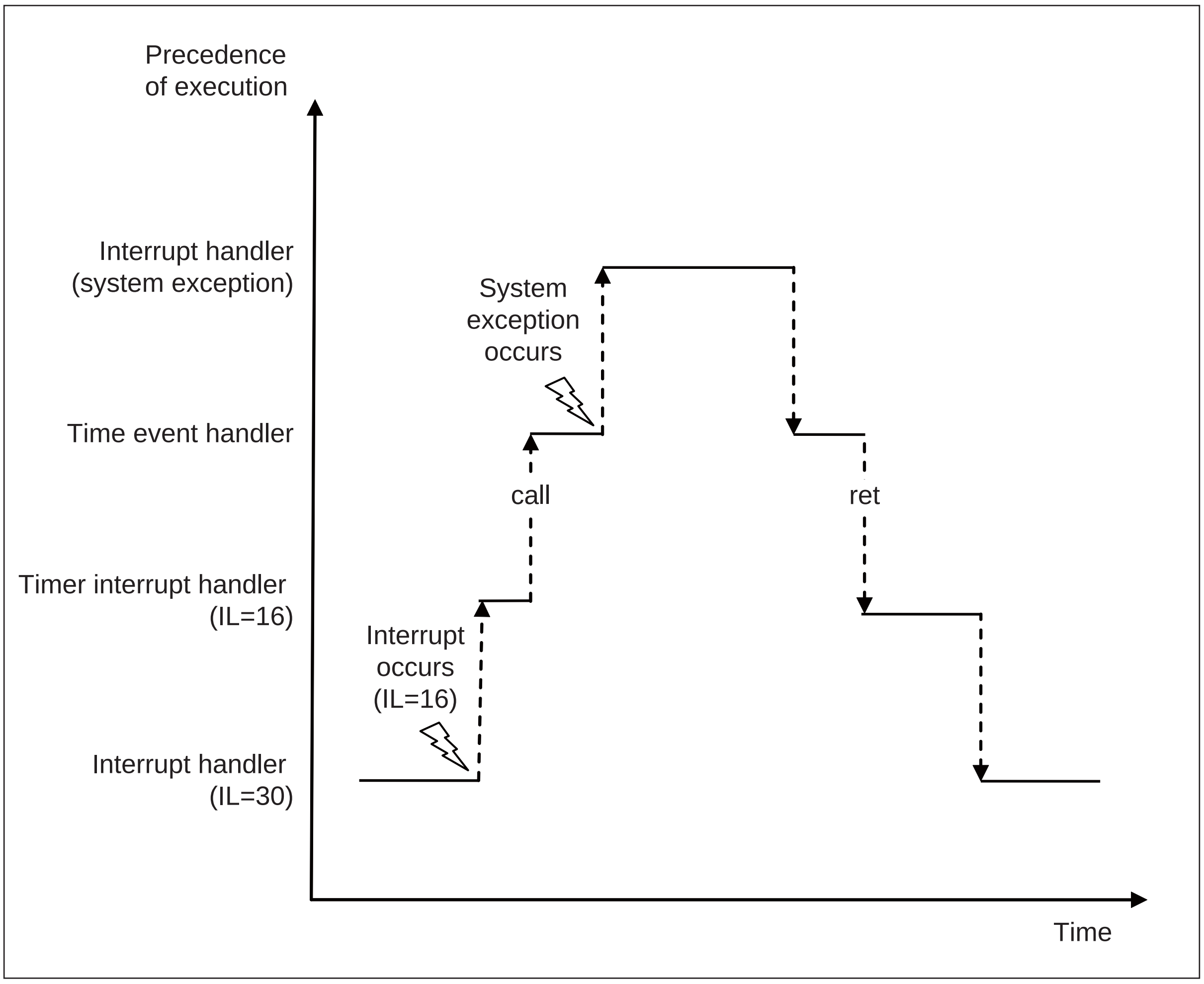
Figure 2.6-2 Precedence of Execution (Tasks vs. Tasks)



■ Precedence of Execution (Handlers vs. Handlers)

In the precedence of execution of handlers, interrupt handlers for system exception sources execute with the highest precedence. The precedence of execution of other interrupt handlers depends on the hardware interrupt level (IL), with the interrupt handlers corresponding to interrupts that have a high interrupt level (the numerical value of the interrupt level is small) executing with precedence. Time event handlers execute as extensions of the timer interrupt handler. The precedence of execution of time event handlers therefore depends on the interrupt level of the timer interrupt.

Figure 2.6-3 Precedence of Execution (Handlers vs. Handlers)



CHAPTER 3

μT-REALOS FUNCTIONS

This chapter explains the functions supported by μT-REALOS.

3.1 Overview of µT-REALOS Functions

This section explains an overview of µT-REALOS functions.

■ Overview of µT-REALOS Functions

µT-REALOS supports the following functions.

- Kernel

  Task management functions

  Task-dependent synchronization functions

  Synchronization and communication functions (semaphores, event flags, mailboxes)

  Extended synchronization and communication functions (mutexes, message buffers, rendezvous ports)

  Memory pool management functions (fixed length memory pool, variable length memory pool)

  Time management functions (system time, cyclic handlers, alarm handlers)

  Interrupt management functions

  System state management functions

  Subsystem management functions

  Device management functions

  Power saving functions
- Configurator

  Kernel configuration function

See "CHAPTER 3 SYSTEM CALL INTERFACE" of the "API Reference" for details on the system calls described in this chapter.

3.2 Task Management Functions

This section explains the task management functions.

■ Task Management Functions

The task management functions are functions for directly operating and referring to the state of a task. Table 3.2-1 shows task management functions and their corresponding system calls.

Table 3.2-1 Task Management Functions and Corresponding System Calls

Function	System Call Name
Create task	tk_cre_tsk
Delete task	tk_del_tsk (Delete dormant task)
	tk_exd_tsk (Exits and deletes its invoking task)
Start task	tk_sta_tsk
Exit task	tk_ext_tsk (Exits its invoking task)
	tk_exd_tsk (Exits and deletes its invoking task)
	tk_ter_tsk (Forcibly terminate other task)
Change task priority	tk_chg_pri
Refer Task Status	tk_ref_tsk
Set Task Registers	tk_set_reg
Get Task Registers	tk_get_reg

Tasks are identified by an ID number that is assigned uniquely to each task. The task ID number is called the task ID.

When a task exits, the kernel does not release resources acquired by the task (semaphore resources, memory blocks, etc). However, mutex locks are released (see "3.5.1 Mutex Functions"). When a task exits, ensure that the user program releases the resources that the task acquired.

3.3 Task Synchronization Functions

This section explains the task synchronization functions.

■ Task Synchronization Functions

The task synchronization functions are functions for performing synchronization by directly operating task portions. Table 3.3-1 shows task synchronization functions and their corresponding systems calls.

Table 3.3-1 Task Synchronization Functions and Corresponding System Calls

Function	System Call Name
Sleep task	tk_slp_tsk
Wakeup task	tk_wup_tsk
Cancel Wakeup Task	tk_can_wup
Release Wait	tk_rel_wai
Suspend Task	tk_sus_tsk
Resume wait task	tk_rsm_tsk
	tk_frsm_tsk (Force Resume Task)
Delay task	tk_dly_tsk

Wakeup requests for a task are queued. That is, when an attempt is made to wake up a task that is not in the sleep state, the attempt is remembered. After that, when the task is to go to a sleep state, it does not enter that state. To realize this, the kernel maintains the number of wakeup requests that have been queued for each task. This is called the "wakeup request queuing count". When the task is started, this count is cleared to 0.

Futhermore, suspend requests for a task are nested. That is, if a task that is already in the SUSPENDED state (including WAITING-SUSPENDED state) is placed again in the SUSPENDED state, the attempt hereof is remembered. After that, when an attempt is made to resume the task in SUSPENDED state (including WAITING-SUSPENDED state), it is not resumed. To realize this, the kernel maintains the number of requests of SUSPENDED state nested for each task. This is called the "suspend request nesting count". When the task is started, this count is cleared to 0.

3.4 Synchronization and Communication Functions

This section explains the synchronization and communication functions.

■ Synchronization and Communication Functions

The synchronization and communication functions are functions for performing synchronization and communication between tasks using task-independent objects.

The synchronization and communication functions support the following functions.

- Semaphore functions
- Event flag functions
- Mailbox functions

3.4.1 Semaphore Functions

This section explains the semaphore functions.

■ Semaphore Functions

Semaphores are objects for representing numerically data of and availability of unused resources (called the semaphore count), and for managing exclusive control and synchronization when using those resources. Table 3.4-1 shows semaphore functions and their corresponding system calls.

Table 3.4-1 Semaphore Functions and Corresponding System Calls

Function	System Call Name
Create semaphore	tk_cre_sem
Delete semaphore	tk_del_sem
Signal Semaphore	tk_sig_sem
Wait on Semaphore	tk_wai_sem
Refer Semaphore Status	tk_ref_sem

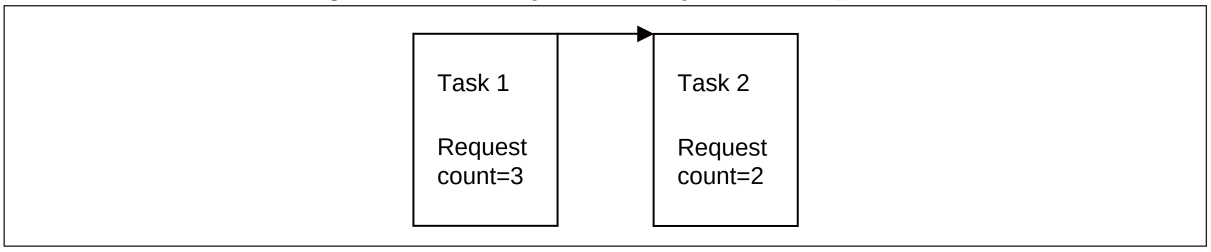
Semaphore objects are identified by an ID number. The semaphore ID number is called the semaphore ID.

Semaphores have a semaphore count and a wait queue of tasks waiting to acquire resources. When m resources are returned (from the event notifier side), the semaphore count increases by m. When n resources are acquired (by the event wait side), the semaphore count decreases by n. When a task attempts to acquire semaphore resources when the number of resources is insufficient (specifically, when the semaphore count reduces to a negative value), a task attempting to acquire resources goes into WAITING until the next time resources are returning. A task waiting for semaphore resources is linked to the wait queue of that semaphore. Furthermore, a maximum resource count can be configured on each semaphore to prevent too many resources from being returning. An error occurs when resources whose semaphore count exceed the maximum are returned to a semaphore (specifically, when the semaphore count increases and exceeds the maximum semaphore count).

The order of the wait queue can be selected from the two options of FIFO order (TA_TFIFO) and task priority order (TA_TPRI). Furthermore, the precedence of resource acquisition can be selected from the two options of task at head of wait queue first (TA_FIRST) or task with smallest request count first (TA_CNT). These are specified as semaphore attributes when the semaphore is created.

Figure 3.4-1 shows the situation when the semaphore count changes from 1 to 2 in a semaphore with the TA_CNT attribute, where Task 1 is skipped and the resources are allocated to Task 2.

Figure 3.4-1 Example of Semaphore Wait Queue



The maximum value of the semaphore count is specified when the semaphore is created. The upper limit on the maximum value of the semaphore count is 0x7FFFFFFF. See Section "3.5.1.1 tk_cre_sem" in the "API Reference" for details.

3.4.2 Event Flag Functions

This section explains the event flag functions.

■ Event Flag Functions

Event flags are objects that perform synchronization by representing the presence or absence of events as bit flags. Table 3.4-2 shows event flag functions and their corresponding system calls.

Table 3.4-2 Event Flag Functions and Corresponding System Calls

Function	System Call Name
Create event flag	tk_cre_flg
Delete event flag	tk_del_flg
Set event flag	tk_set_flg
Clear event flag	tk_clr_flg
Wait Event Flag	tk_wai_flg
Refer Event Flag Status	tk_ref_flg

Event flag objects are identified by an ID number. The event flag ID number is called the event flag ID.

Event flags contain a bit pattern where each bit represents the presence or absence of the corresponding event, and a wait queue of tasks waiting for those event flags. Sometimes the bit pattern of an event flag is simply called the event flag. The event notifier side can set or clear the specified bits of the event flag. The event wait side can bring a task to the event flag wait state until all or some of the specified bits of the event flag are set.

A task waiting for event flag is linked to the wait queue of that event flag. The order of the wait queue can be selected from the two options of FIFO order (TA_TFIFO) and task priority order (TA_TPRI). This is specified as a part of flag attributes when the flag is created.

The conditions for release from the event flag wait state can specify either of the two attributes of AND wait (TWF_ANDW) or OR wait (TWF_ORW). These attributes specify how the release from WAITING state operates when waiting for multiple events. For the AND wait, the WAITING state is not released until all of the events are signaled, whereas for the OR wait, the WAITING state is released when even one of the events being waited for is signaled. It is also possible to specify whether or not to clear the bits when the wait is released. TWF_CLR can be used to clear all bits, while TWF_BITCLR can be used to selectively clear bits corresponding to event flag wait criteria.

µT-REALOS manages event generation using 32-bit patterns.

3.4.3 Mailbox Functions

This section explains the mailbox functions.

■ Mailbox Functions

Mailboxes are objects that perform synchronization and communication by receiving messages that are stored in memory. Table 3.4-3 shows mailbox functions and their corresponding system calls.

Table 3.4-3 Mailbox Functions and Corresponding System Calls

Function	System Call Name
Create mailbox	tk_cre_mbx
Delete mailbox	tk_del_mbx
Send Message to Mailbox	tk_snd_mbx
Receive Message from Mailbox	tk_rcv_mbx
Refer Mailbox Status	tk_ref_mbx

Mailbox objects are identified by an ID number. The mailbox ID number is called the mailbox ID.

Mailboxes have a message queue for storing messages that have been sent, and a wait queue for tasks that are waiting to receive a message. The message-sending side (the event notifier side) places the messages to be sent in the message queue. The order of the message queue can be selected from the two options of FIFO order (TA_MFIFO) and message priority order (TA_MPRI) when the mailbox is created.

The message-receiving side (the event wait side) retrieves a single message from the message queue.

If there are no messages in the message queue, the task enters a state of waiting for receipt from the mailbox until the next message is sent. Tasks that enter a state of waiting for receipt from the mailbox linked to the wait queue of that mailbox. The order of the wait queue can be selected from the two options of FIFO order (TA_TFIFO) and task priority order (TA_TPRI). This is specified as a part of mailbox attributes when the mailbox is created.

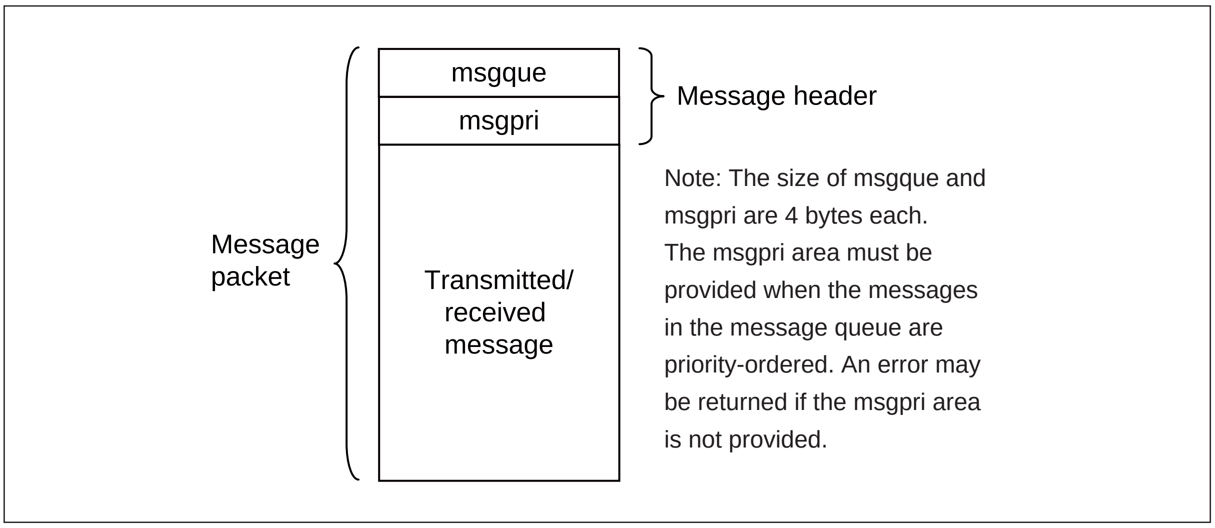
The information that is actually sent and received by the mailbox is only the starting address of a message in memory. This means that the contents of messages that are sent and received are not copied.

The kernel manages the messages in the message queue using a linked list.

The user program should allocate an area (msgque) at the top of a message being sent for the kernel to use for the linked list. This area is called the message header. Furthermore, if the message queue is ordered by message priority, an area for holding the message priority (msgpri) also needs to be reserved in the message header. The message header and the following area where the application stores the message are collectively called a message packet. System calls for sending messages to a mailbox take the starting address of the message packet (pk_msg) as a parameter. Furthermore, system calls for receiving messages from a mailbox return the starting address of the message packet as the return value. If the message queue is arranged in the priority order of the message, an area for storing the priority order of the message(msgpri) must exist in the message header.

Figure 3.4-2 shows the message packet format of priority-ordered messages.

Figure 3.4-2 Message Packet Format


msgque
msgpri
Message header
Message packet
Transmitted/ received message
Note: The size of msgque and msgpri are 4 bytes each.
The msgpri area must be provided when the messages in the message queue are priority-ordered. An error may be returned if the msgpri area is not provided.

■ Additional Notes

Because the mailbox functions allocate the area for the message header by the user program, there is no upper limit on the number of messages that can be placed in a message queue. Furthermore, the system calls for sending messages do not enter the WAITING state.

Message packets are able use memory blocks dynamically allocated from the fixed-size memory pool or variable-size memory pool, or statically allocated regions.

Typical usage is for the sending task to allocate a memory block from the memory pool and send this as a message packet, and for the receiving task to directly release the memory block back to the memory pool after reading the contents of the message.

3.5 Extended Synchronization and Communication Functions

This section explains the extended synchronization and communication functions.

■ Extended Synchronization and Communication Functions

The extended synchronization and communication functions are functions for performing high-level synchronization and communication between tasks using task-independent objects.

The extended synchronization and communication functions support the following functions.

- Mutex functions
- Message buffer functions
- Rendezvous port functions

3.5.1 Mutex Functions

This section explains the mutex functions.

■ Mutex Functions

Mutexes are objects that perform exclusive control between tasks that use a shared resource. Table 3.5-1 shows mutex functions and their corresponding system calls.

Table 3.5-1 Mutex Functions and Corresponding System Calls

Function	System Call Name
Create mutex	tk_cre_mtx
Delete mutex	tk_del_mtx
Lock mutex	tk_loc_mtx
Unlock mutex	tk_unl_mtx
Refer Mutex Status	tk_ref_mtx

The mutexes support the priority inheritance protocol and priority ceiling protocol as a mechanism to prevent priority inversion due to unlimited exclusive control.

Generally, priority inversion refers to a phenomenon where due to one task having obtained resources, another task with higher priority cannot operate. To prevent this, the priority inheritance protocol sets the highest priority of task groups which share resources on a task which has obtained resources.

On the other hand, the priority ceiling protocol sets ceiling priority for each resource and sets this priority on a task which has obtained resources.

Mutex objects are identified by an ID number. The mutex ID number is called the mutex ID.

Mutexes have a state that can be locked or unlocked, and a wait queue of tasks waiting to lock the mutex. Furthermore, the kernel manages the following objects: the tasks that are locking each mutex and the mutexes that are locked by each task.

A task locks the mutex before using the resource. If the mutex is already locked by another task, the task waits for the mutex to become unlocked.

Tasks waiting for the mutex to become unlocked are added to the wait queue for that mutex. The wait queue order can be selected from one of the following 2 options.

- FIFO order (TA_TFIFO)
- Task priority order (TA_TPRI, TA_INHERIT, TA_CEILING)

Task priority can be further selected from one of the following 3 options.

- Simple priority order (TA_TPRI)
- Priority inheritance protocol (TA_INHERIT)
- Priority ceiling protocol (TA_CEILING)

These are specified as parts of mutex attributes when the mutex is created.

When the task finishes using the resource, the task releases the lock on the mutex.

If TA_INHERIT or TA_CEILING attribute is used, the current priority of a task that has a lock on a mutex is changed in order to prevent unlimited priority inversion. The current priority of a task is changed so that it always equals the highest value from among the following priorities.

- The base priority of the task that is locking the mutex
- The current priority of the task that has the highest current priority from among the tasks that are waiting to lock that mutex if the task is locking a mutex that has the TA_INHERIT attribute
- If the task is locking a mutex that has the TA_CEILING attribute, the ceiling priority of the mutex that has the highest ceiling priority from among the mutexes being locked by that task

If the current priority of a task that is waiting for a mutex that has the TA_INHERIT attribute is changed as a result of a mutex operation or the base priority being changed by tk_chg_pri, the current priority of the task that is locking that mutex may need to be changed. This is called transitive priority inheritance. Furthermore, if that task is waiting for another mutex that has the TA_INHERIT attribute, then transitive priority inheritance processing may be needed for the task that is locking that mutex.

The following processing is performed when the current priority of a task is changed as the result of acquisition of a mutex.

- If a task that has changed its priority is in a runnable state, the precedence of the task is changed based on the priority after the change (the task will have the lowest precedence from among the tasks that have the same priority after the priority has been changed).
- If the task that has changed its priority is linked to some kind of task priority ordered wait queue, the order within the wait queue is changed based on the priority after the change (the task will have the lowest precedence from among the tasks that have the same priority after the priority has been changed).
- If a task is still locking any mutexes when the task ends, the locks are released from all of those mutexes. If the tasks is locking multiple mutexes, those mutexes are released in order starting from the mutexes that were allocated last.

See Section "3.6.1.4 tk_unl_mtx" in the "API Reference" for details on the specific lock release process.

■ Task Priority Control

The task priority that locks the mutexes changes the priority according to the priority control rule accompanied by the task priority which has the mutexes and change of its priority.

■ Additional Notes

Mutexes that have the TA_TFIFO attribute or TA_TPRI attribute have the same functions as a semaphore with a maximum resource count of 1 (binary semaphore). However, mutexes differ in that the lock can only be released by the locking task, and the lock is automatically released when the task ends.

Figure 3.5-1 is used to show an example of mutex behavior when the priority inheritance protocol is selected.

If Task C is running while the mutex is locked, the task priority is the same as the base priority of Task C. If Task A, which has higher priority, is activated, Task A is executed. If Task A tries to lock the mutex, Task A is transitioned into wait state and Task C is executed with the task priority of Task A. Even if Task B transitions into ready state, it is not transitioned into run state while Task C is running. Task C continues to run until it unlocks the mutex. The task priority of Task C then returns to its normal priority, and Task A is executed.

Figure 3.5-1 Priority Inheritance Protocol

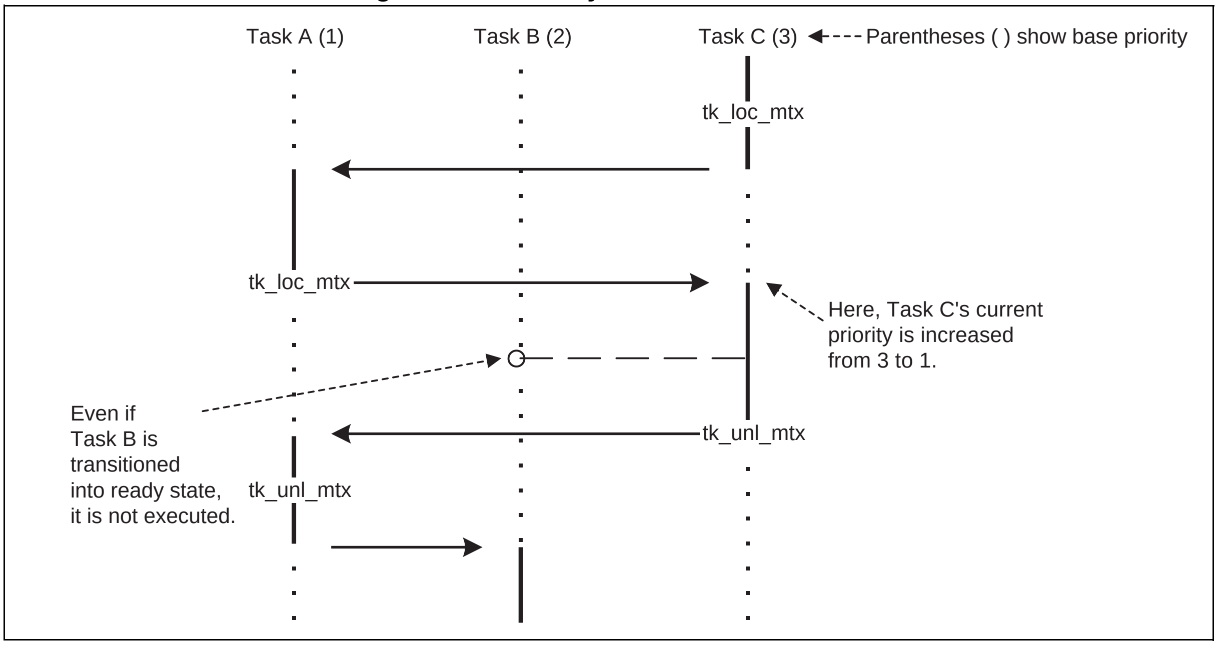
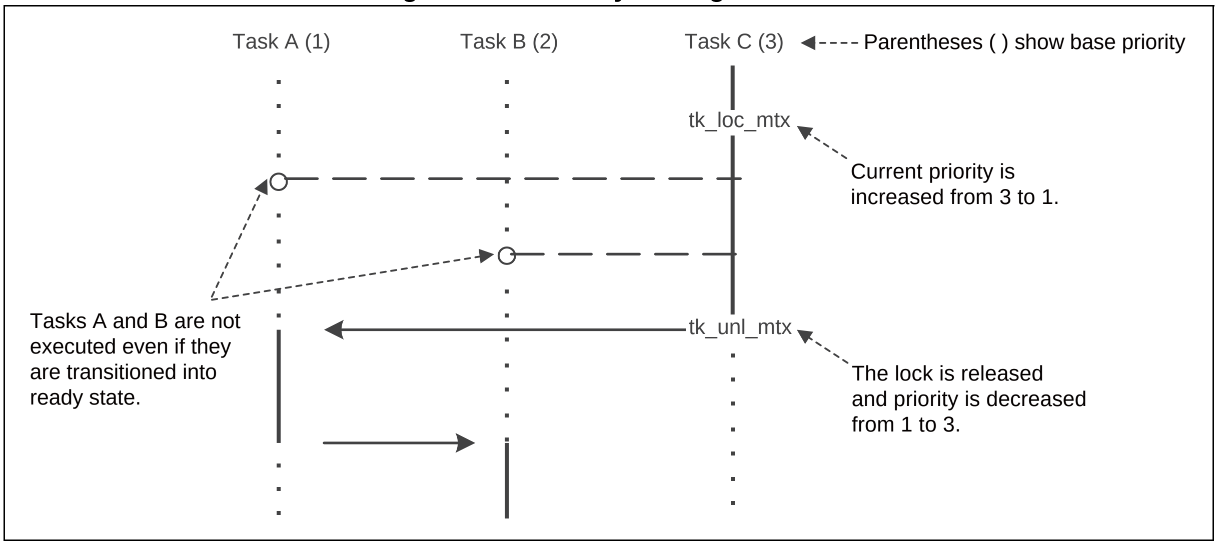

Task A (1)
Task B (2)
Task C (3)
Parentheses ( ) show base priority
tk_loc_mtx
tk_loc_mtx
Here, Task C's current priority is increased from 3 to 1.
Even if Task B is transitioned into ready state, it is not executed.
tk_unl_mtx
tk_unl_mtx

Figure 3.5-2 is used to show an example of mutex behavior when the priority ceiling protocol is selected.

Assume that the mutex ceiling protocol has the same priority as Task A. If Task C locks the mutex, Task C continues to run with the same priority as Task A even if Tasks A and B are transitioned into ready state. When Task C unlocks the mutex, its priority returns to its original priority, and Task A is executed next, followed by Task B.

Figure 3.5-2 Priority Ceiling Protocol


Task A (1)
Task B (2)
Task C (3)
Parentheses ( ) show base priority
tk_loc_mtx
Current priority is increased from 3 to 1.
Tasks A and B are not executed even if they are transitioned into ready state.
tk_unl_mtx
The lock is released and priority is decreased from 1 to 3.

3.5.2 Message Buffer Functions

This section explains the message buffer functions.

■ Message Buffer Functions

Message buffers are objects that perform synchronization and communication by receiving variable-length messages. Table 3.5-2 shows message buffer functions and their corresponding system calls.

Table 3.5-2 Message Buffer Functions and Corresponding System Calls

Function	System Call Name
Create message buffer	tk_cre_mbf
Delete message buffer	tk_del_mbf
Send Message to Message Buffer	tk_snd_mbf
Receive Message from Message Buffer	tk_rcv_mbf
Refer Message Buffer Status	tk_ref_mbf

Message buffer objects are identified by an ID number. The message buffer ID number is called the message buffer ID.

Message buffers have a wait queue of tasks waiting to send messages (send wait queue) and a wait queue of tasks waiting to receive messages (receive wait queue). The message buffer also has a message buffer area for storing sent messages.

The message-sending side (the event notifier side) copies the messages to be sent into the message buffer. If there is not enough free space in the message buffer area, the task waits for sending a message to message buffer until there is enough free space in the message buffer area. Tasks waiting to send a message to message buffer are linked to the send wait queue of that message buffer. The order of the send wait queue can be selected from the two options of FIFO order (TA_TFIFO) and task priority order (TA_TPRI). This is specified as a part of message buffer attributes when the message buffer is created.

The message-receiving side (the event wait side) retrieves a single message from the message buffer. If there are no messages in the message buffer, the task waits for receiving a message from message buffer until the next message is sent. Tasks waiting for receiving a message from message buffer are linked to the receive wait queue of that message buffer. The order of the receive wait queue is always the FIFO order.

Synchronous messaging functionality can be obtained by setting the size of the message buffer area to zero. This means that both the sending task and the receiving task wait for each-other to make the system call, and pass the message between them when both tasks have made the system call.

The message buffer functions provide the following functions using the corresponding system calls.

■ Additional Notes

Figure 3.5-3 shows the operation of a message buffer when the size of the message buffer area is set to 0. In this diagram, Task A and Task B are executing asynchronously.

[Task A calls tk_snd_mbf first ((a) of Figure 3.5-3)]

Task A waits to send the message buffer until Task B calls tk_rcv_mbf. When Task B calls tk_rcv_mbf, the message is transmitted from Task A to Task B.

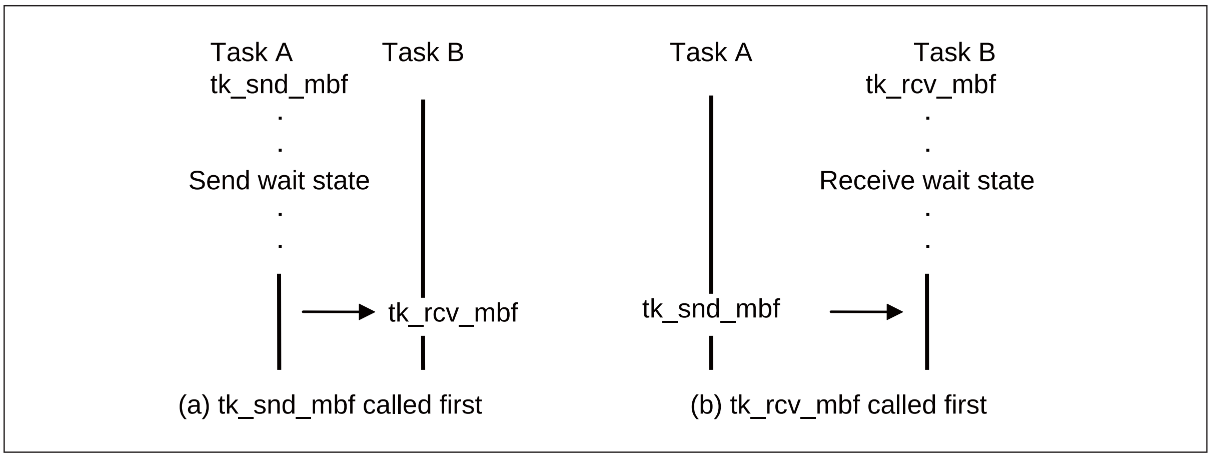
Then, according to precedence, Tasks A and B are transitioned into run state or ready state.

[Task B calls tk_rcv_mbf first ((b) of Figure 3.5-3)]

Task B waits to receive the message buffer until Task A calls tk_snd_mbf. When Task A calls tk_snd_mbf, the message is transmitted from Task A to Task B.

Then, according to precedence, Tasks A and B are transitioned into run state or ready state.

Figure 3.5-3 Synchronous Communication Using a Message Buffer



Tasks that are waiting to send to a message buffer send messages in the order that they are linked to the wait queue. For example, consider the situation where Task A which is attempting to send a 40-byte message to the message buffer and Task B which is attempting to send a 10-byte message, and these tasks are linked into the wait queue in this order. Now suppose that 20 bytes of free space are created by another task receiving a message. In this situation, Task B is unable to send its message until Task A sends its message.

Message buffers are different from mailboxes because they transfer variable-length messages by copying.

3.5.3 Rendezvous Port Functions

This section explains the rendezvous port functions.

■ Rendezvous Port Functions

Rendezvous ports provide intertask synchronous communication functionality, and support a single sequence where one task requests processing of another task and the other task then returns the processing result to the first task. The object that synchronizes the waiting of both tasks is called a rendezvous port. Although the rendezvous port functions can be used to implement a client/server model of intertask communication, they provide a synchronous communication model that is more flexible than the client/server model. Table 3.5-3 shows rendezvous port functions and their corresponding system calls.

Table 3.5-3 Rendezvous Port Functions and Corresponding System Calls

Function	System Call Name
Create Port for Rendezvous	tk_cre_por
Delete Port for Rendezvous	tk_del_por
Call Port for Rendezvous	tk_cal_por
Accept Port for Rendezvous	tk_acp_por
Reply Rendezvous	tk_rpl_rdv
Forward Rendezvous to Another Port	tk_fwd_por
Refer Port Status	tk_ref_por

Rendezvous port objects are identified by an ID number. The rendezvous port ID number is called the rendezvous port ID.

The task that makes the processing request to the rendezvous port (the client-side task) specifies the rendezvous port, rendezvous conditions, and a message containing information regarding the processing being requested (called the call message) and calls the rendezvous port. On the other hand, the task that accepts the processing request at the rendezvous port (the server-side task) specifies the rendezvous port and rendezvous conditions, then accepts processing at the rendezvous port. The rendezvous parameters are specified as a bit pattern. For a given rendezvous port, a rendezvous is established if the result of logical bitwise ANDing of the rendezvous parameters bit pattern of the calling tasking and the rendezvous parameters bit pattern of the accepting task is non-zero. The task that calls the rendezvous port enters the rendezvous call wait state until the rendezvous is established. Contrarily, the task that accepts the processing request at the rendezvous port is in wait state until the rendezvous is established.

Once the rendezvous is established, the call message is passed from the task that called the rendezvous port to the task that accepted the rendezvous. The task that called the rendezvous port then enters the rendezvous completion wait state and waits for the requested processing to finish. On the other hand, the wait state is released for the task that accepted the processing at the rendezvous port, and the requested process is executed. When the task that accepted the processing at the rendezvous port is completed, processing results are handed to the called task as a reply message, and the rendezvous is terminated. At this time, the task that called the rendezvous port is released from the rendezvous completion wait state.

Rendezvous ports have a call wait queue for linking tasks in the rendezvous call wait state, and a receive wait queue for linking tasks in the rendezvous accept wait state. When the rendezvous is established, both tasks involved in establishing the rendezvous are detached. In other words, the rendezvous port does not hold a wait queue to connect tasks waiting for a rendezvous to terminate. Nor does it not hold information regarding processes accepted at the rendezvous port or tasks running requested processes.

The kernel allocates object numbers for identifying rendezvous that are established at the same time. The rendezvous object number is called the rendezvous number. The lower 16 bits of the rendezvous number is the task ID of the task that called the rendezvous port, and the upper 16 bits is a sequential number that is incremented by 1 for each rendezvous accepted. This means that even when rendezvous port are called by the same task, different rendezvous numbers are allocated to the first rendezvous and the second rendezvous.

■ Additional Notes

Figure 3.5-4 shows the rendezvous operation. In this diagram, Task A and Task B are executing asynchronously.

[Task A calls tk_cal_por first ((a) of Figure 3.5-4)]

Task A is in wait state for the rendezvous to be called until Task B calls tk_acp_por. The rendezvous is established when Task B calls tk_acp_por, and Task A will be in wait state for the rendezvous to terminate.

When Task B calls tk_rpl_rdv, Task A is released from wait state for the rendezvous to terminate.

Then both tasks are transitioned to run state.

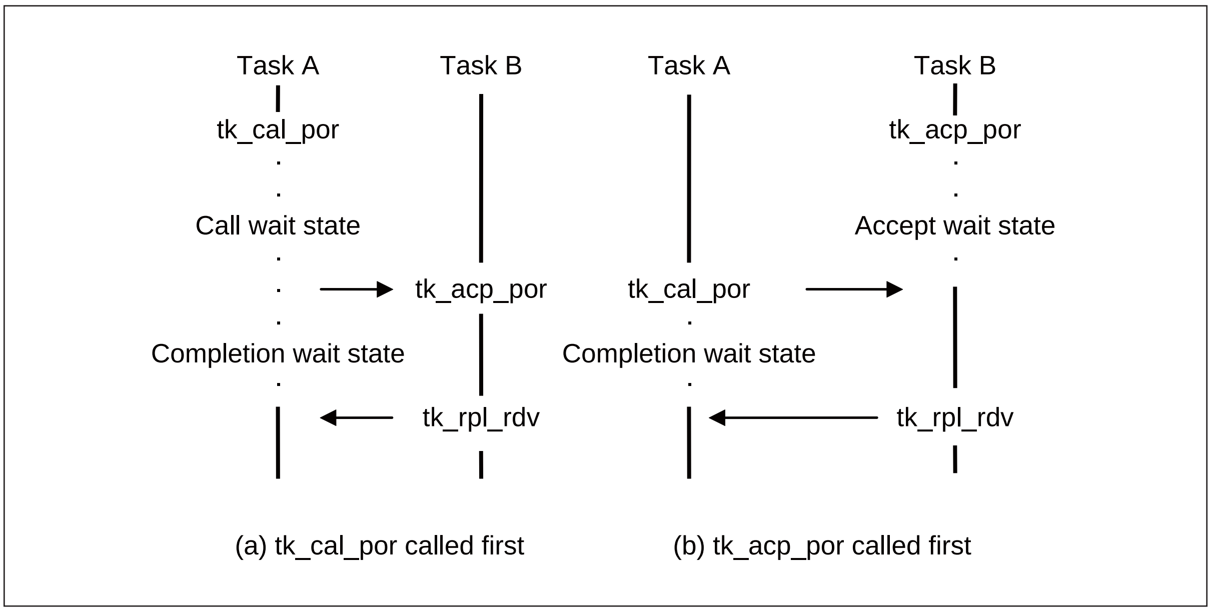
[Task B calls tk_acp_por first ((b) of Figure 3.5-4)]

Task B is in wait state for the rendezvous to accept until Task A calls tk_cal_por. The rendezvous is established when Task A calls tk_cal_por, and Task A is in wait state for the rendezvous to terminate, while Task B is released from wait state for the rendezvous to accept.

When Task B calls tk_rpl_rdv, Task A is released from wait state for the rendezvous to terminate.

Then both tasks are transitioned to run state.

Figure 3.5-4 Rendezvous Operation



3.6 Memory Pool Management Functions

This section explains the memory pool management functions.

■ Memory Pool Management Functions

The memory pool management functions are functions for managing memory pools and allocating regions of memory (memory blocks) for use by user programs.

The available memory pools are the fixed-size memory pool and the variable-size memory pool. These two memory pools are separate objects and are accessed by different system calls. While the size of memory blocks obtained from fixed-size memory pools are fixed, the size of memory blocks obtained from variable-size memory pools can be specified.

The memory pool management functions support the following functions.

- Fixed-size memory pool functions
- Variable-size memory pool functions

3.6.1 Fixed-size Memory Pool Functions

This section explains the fixed-size memory pool functions.

■ Fixed-size Memory Pool Functions

Fixed-size memory pool are objects that perform dynamic management of fixed size memory blocks. Table 3.6-1 shows fixed-size memory pool functions and their corresponding system calls.

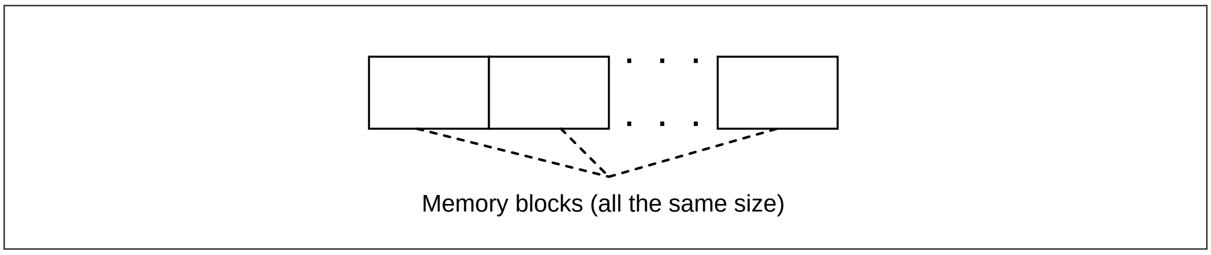
Table 3.6-1 Fixed-Size Memory Pool Functions and Corresponding System Calls

Function	System Call Name
Create fixed-size memory pool	tk_cre_mpf
Delete fixed-size memory pool	tk_del_mpf
Get Fixed-size Memory Block	tk_get_mpf
Release Fixed-size Memory Block	tk_rel_mpf
Refer Fixed-size Memory Pool Status	tk_ref_mpf

The fixed-size memory pool objects are identified by an ID number. The fixed-size memory pool ID number is called the fixed-size memory pool ID.

Fixed-size memory pool have a region of memory that is used as the fixed-size memory pool (this is called the fixed-size memory pool region, or simply the memory pool region), and a wait queue for tasks that are waiting to get a memory block. If there is no free space in the memory pool region, a task that gets a memory block from a fixed-size memory pool enters the fixed length memory block acquisition wait state until the next memory block is returned. Tasks that enter the fixed length memory block acquisition wait state are linked to the wait queue of that fixed-size memory pool. The order of the wait queue can be selected from the two options of FIFO order (TA_TFIFO) and task priority order (TA_TPRI). This is specified as a part of fixed-size memory pool attributes when the fixed-size memory pool is created.

Figure 3.6-1 Memory Region of a Fixed-size Memory Pool



3.6.2 Variable-size Memory Pool Functions

This section explains the variable-size memory pool functions.

■ Variable-size Memory Pool Functions

Variable-size memory pool are objects for dynamically managing arbitrary size memory blocks. Table 3.6-2 shows variable-size memory pool functions and their corresponding system calls.

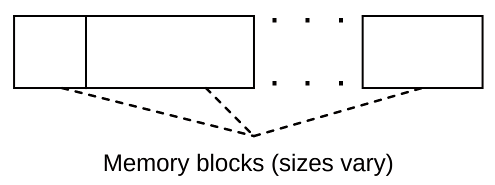
Table 3.6-2 Variable-Size Memory Pool Functions and Corresponding System Calls

Function	System Call Name
Create variable-size memory pool	tk_cre_mpl
Delete variable-size memory pool	tk_del_mpl
Get Variable-size Memory Block	tk_get_mpl
Release Variable-size Memory Block	tk_rel_mpl
Refer Variable-size Memory Pool Status	tk_ref_mpl

The variable-size memory pool objects are identified by an ID number. The variable-size memory pool ID number is called the variable-size memory pool ID.

Variable-size memory pool have a region of memory that is used as the variable-size memory pool (this is called the variable-size memory pool region, or simply the memory pool region), and a wait queue for tasks that are waiting to get a memory block. If there is insufficient free space in the memory pool region when a task gets a memory block from the variable-size memory pool, the task enters the variable length memory block acquisition WAITING until a memory block of sufficient size is returned. Tasks that enter the variable length memory block acquisition WAITING are linked to the wait queue of that variable-size memory pool. The order of the wait queue can be selected from the two options of FIFO order (TA_TFIFO) and task priority order (TA_TPRI). This is specified as a part of variable-size memory pool attributes when the variable-size memory pool is created.

Figure 3.6-2 Memory Region of a Variable-size Memory Pool



3.7 Time Management Functions

This section explains the time management functions.

■ Time Management Functions

The time management functions are functions for performing time-dependent processing. The functions include functions for system time management, cyclic handlers, and alarm handlers. Cyclic handlers and alarm handlers are collectively referred to as time event handlers.

The time management functions support the following functions.

- System time management functions
- Cyclic handler functions
- Alarm handler functions

3.7.1 System Time Management Functions

This section explains the system time management functions.

■ System Time Management Functions

System time management functions are used to update, set and reference the system time, as well as to reference the system operating time. Table 3.7-1 shows system time management functions and their corresponding system calls.

Table 3.7-1 System Time Management Functions and Corresponding System Calls

Function	System Call Name
Signal Time	isig_tim
Set Time	tk_set_tim
Get Time	tk_get_tim
Get Operating Time	tk_get_otm

µT-REALOS uses isig_tim to update the system time for user programs. This system call increases the system time by 1.

isig_tim is a system call unique to µT-REALOS.

Because resolution of system time is processed in units of 1ms, interrupts are made in 1ms cycles using an interval timer. System time is updated by calling isig_tim from the interrupt handler.

System operating time shows the elapsed time since the system was activated. Unlike system time, it does not affect system time settings when tk_set_tim is called.

■ System Time

The system time is represented by the accumulated number of milliseconds since the 1st January 1985 (GMT). For example, a system time value of 0 represents 12:00:00 AM on 1st January 1985 (GMT). A system time value of 1000 represents 12:00:01 AM on 1st January 1985 (GMT). Because µT-REALOS does not have a function to automatically set the current time when the system starts, the current time must be set by the user program.

3.7.2 Cyclic Handler Functions

This section explains the cyclic handler functions.

■ Cyclic Handler Functions

Cyclic handlers are time event handlers that activate at a fixed period. Table 3.7-2 shows cyclic handler functions and their corresponding system calls

Table 3.7-2 Cyclic Handler Functions and Corresponding System Calls

Function	System Call Name
Create cyclic handler	tk_cre_cyc
Delete cyclic handler	tk_del_cyc
Start cyclic handler	tk_sta_cyc
	tk_cre_cyc (Specify TA_STA to create and start cyclic handler)
Stop cyclic handler	tk_stp_cyc
Refer Cyclic Handler Status	tk_ref_cyc

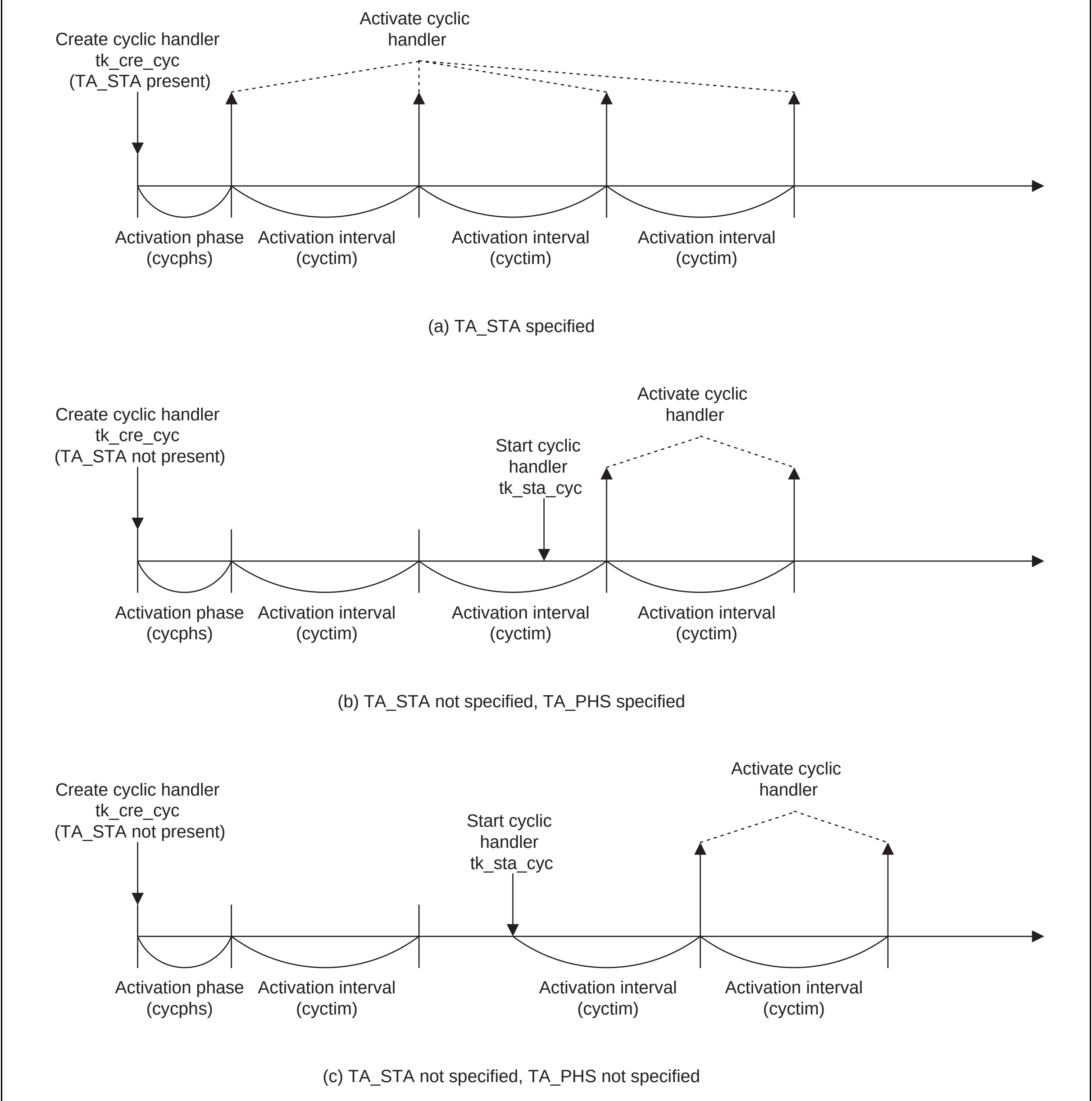
Cyclic handler objects are identified by an ID number. The cyclic handler ID number is called the cyclic handler ID.

The activation interval and activation phase for each cyclic handler can be set when the cyclic handler is created. When handling a cyclic handler, the kernel determines the time when the cyclic handler should be activated next from the specified activation interval and activation phase. When the time when the cyclic handler should activate is reached, the cyclic handler is activated with the extended information (exinf) of that cyclic handler as a parameter. In this case, the time when the handler should next activate is set to the time when the cyclic handler should have activated plus the activation interval. When the operation of a cyclic handler is started, the time when the handler should next activate may need to be reset.

Cyclic handlers can either be in the operating state or the non-operating state. When a cyclic handler is in the non-operating state, the cyclic handler is not activated even when the time when the cyclic handler is supposed to activate is reached, and only the time when the handler should next activate is set. When the system call to start the operation of the cyclic handler (tk_sta_cyc) is called, the cyclic handler is placed in the operating state and the time when the cyclic handler should next activate is reset if necessary. When the system call to stop the operation of the cyclic handler (tk_stp_cyc) is called, the cyclic handler changes to the non-operating state. After the cyclic handler is created, either the operating or non-operating state is determined by the cyclic handler attributes.

See Section "4.6 Cyclic Handler" for details on the format of cyclic handlers.

Figure 3.7-1 Activation Timing for Cyclic Handlers


Create cyclic handler
tk_cre_cyc
(TA_STA present)
Activate cyclic handler
Activation phase (cycphs)
Activation interval (cyctim)
Activation interval (cyctim)
Activation interval (cyctim)
(a) TA_STA specified
Create cyclic handler
tk_cre_cyc
(TA_STA not present)
Start cyclic handler
tk_sta_cyc
Activate cyclic handler
Activation phase (cycphs)
Activation interval (cyctim)
Activation interval (cyctim)
Activation interval (cyctim)
(b) TA_STA not specified, TA_PHS specified
Create cyclic handler
tk_cre_cyc
(TA_STA not present)
Start cyclic handler
tk_sta_cyc
Activate cyclic handler
Activation phase (cycphs)
Activation interval (cyctim)
Activation interval (cyctim)
Activation interval (cyctim)
(c) TA_STA not specified, TA_PHS not specified

For details on TA_PHS, see "3.8.2.1 tk_cre_cyc(Create Cyclic Handler)" in "API Reference".

3.7.3 Alarm Handler Functions

This section explains the alarm handler functions.

■ Alarm Handler Functions

Alarm handlers are time event handlers that activate at a specified time. Table 3.7-3 shows alarm handlers functions and their corresponding system calls.

Table 3.7-3 Alarm Handlers Functions and Corresponding System Calls

Function	System Call Name
Create alarm handler	tk_cre_alm
Delete alarm handler	tk_del_alm
Start alarm handler	tk_sta_alm
Stop alarm handler	tk_stp_alm
Refer Alarm Handler Status	tk_ref_alm

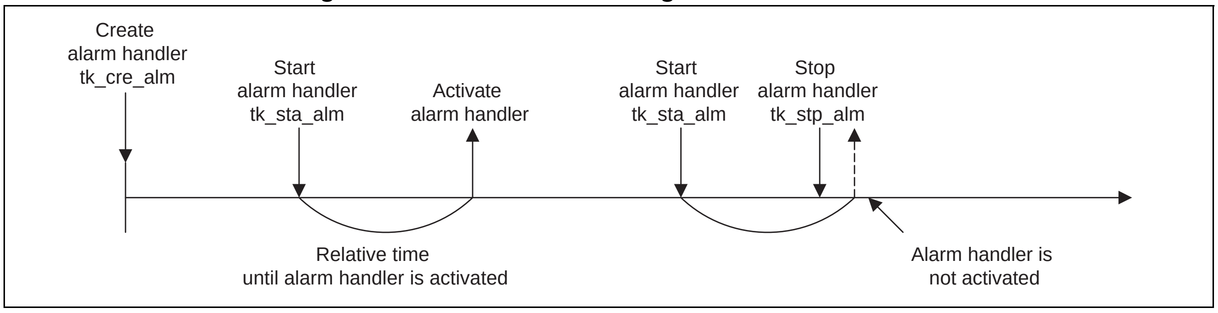
Alarm handler objects are identified by an ID number. The alarm handler ID number is called the alarm handler ID.

The time when an alarm handler activates (this is called the alarm handler activation time) can be set for each alarm handler. When the alarm handler activation time is reached, the alarm handler is activated with the extended information (exinf) of that alarm handler as a parameter.

Immediately after an alarm handler is created, the alarm handler activation time is not set and the alarm handler is stopped. When the system call to start the operation of an alarm handler (tk_sta_alm) is called, the alarm handler activates after the specified relative time. When the system call to stop the operation of an alarm handler (tk_stp_alm) is called, the alarm handler activation time setting is cleared. In addition, when an alarm handler activates, the alarm handler activation time setting is cleared and the alarm handler is stopped.

See Section "4.7 Alarm Handler" for details on writing alarm handlers.

Figure 3.7-2 Activation Timing for Alarm Handlers



3.8 Interrupt Management Functions

This section explains the interrupt management functions.

■ Interrupt Management Functions

The interrupt management functions are functions for performing operations such as defining handlers for external interrupts and system exceptions, and controlling interrupts. Table 3.8-1 shows interrupt management functions and their corresponding system calls.

Table 3.8-1 Interrupt Management Functions and Corresponding System Calls

Function	System Call Name
Define interrupt handler	tk_def_int
Return from interrupt handler	tk_ref_int
Prohibits all external interrupts	DI
Enables all external interrupts	EI
Checks the external interrupt disabled status	isDI

The interrupt management functions provide the following functions using the corresponding system calls.

- System calls that specify the invoking task and system calls that enter a WAITING state produce an error.

During execution in the task-independent portion, if a dispatch request is made during the processing of a system call, the dispatch is delayed until the system leaves the task-independent portion. This is called delayed dispatching.

See Section "4.8 Interrupt Handler" for details on writing interrupt handlers.

These functions manipulate the CPU registers to set the interrupts enabled/disabled. DI, EI, and isDI cannot be called from the task-independent portion or from a state where dispatch and interrupts are disabled.

3.9 System State Management Functions

This section explains the system state management functions.

■ System State Management Functions

The system state management functions are functions for changing and referring to the state of the system. Table 3.9-1 shows system state management functions and their corresponding system calls.

Table 3.9-1 System State Management Functions and Corresponding System Calls

Function	System Call Name
Rotate Ready Queue	tk_rot_rdq
Get Task Identifier	tk_get_tid
Disable dispatch	tk_dis_dsp
Enable dispatch	tk_ena_dsp
Refer System Status	tk_ref_sys
Refer Version Information	tk_ref_ver

3.10 Subsystem Management Functions

This section explains the subsystem management functions.

■ Subsystem Management Functions

The subsystem management functions consist of the extended SVC handlers for accepting requests. The subsystem management functions provide the following functions depending on the corresponding system calls. Table 3.10-1 shows subsystem management functions and their corresponding system calls.

Table 3.10-1 Subsystem Management Functions and Corresponding System Calls

Function	System Call Name
Define subsystem	tk_def_ssy
Refer Subsystem Status	tk_ref_ssy

3.11 Device Management Functions

This section explains the device management functions.

■ Device Management Functions

Device management functions provide a common API for handling different devices. Table 3.11-1 shows device management functions and their corresponding system calls.

Table 3.11-1 Device Management Functions and Corresponding System Calls

Function	System Call Name
Define Device	tk_def_dev
Refer Initial Device Information	tk_ref_idv
Open device	tk_opn_dev
Close device	tk_cls_dev
Read Device	tk_rea_dev
Synchronous Read Device	tk_srea_dev
Write Device	tk_wri_dev
Synchronous Write Device	tk_swri_dev
Wait Device	tk_wai_dev
Suspend device	tk_sus_dev
Get Device	tk_get_dev
Get device information	tk_ref_dev
	tk_oref_dev
List Device	tk_lst_dev
Event Device	tk_evt_dev

The system calls that can be called depending on the device registration and open state are as follows.

Table 3.11-2 Callable System Calls

Device registered	Device opened	Callable system calls
No	No	tk_def_dev
Yes	No	tk_opn_dev, tk_ref_idv, tk_get_dev, tk_ref_dev, tk_lst_dev, tk_sus_dev, tk_def_dev
	Yes	All system calls of the device management function

The specifications for the interface between the device drivers and the kernel are defined by the device driver interface. The device driver interface defines the device processing functions that are called from the kernel, the format of data passed between the kernel and the device driver, etc.

Because the device driver interface is supported by all µT-Kernel specification OSs, device drivers that were created in compliance with device driver interface have improved portability between µT-Kernel specification OSs.

See "CHAPTER 4 DEVICE DRIVER INTERFACE" of the "API Reference" for details on the device driver interface.

3.12 Power Saving Functions

This section explains the power saving functions.

■ Power Saving Functions

The µT-REALOS supports a function to call a user-defined power saving routine when it has switched to the idle state. This is called the power saving function.

The processing performed by the power saving routine can be written freely by the user to suit the target hardware. This power saving routine is useful because it is defined using the static API of the configurator. See "3.13 Kernel Configuration Function" for details on how to define the power saving routine and to "4.10 Power Saving Routine" for details on writing the power saving routine.

3.13 Kernel Configuration Function

This section explains the kernel configuration function.

■ Kernel Configuration Function

The kernel configuration function provide the functionality for the user to define the configuration of the kernel, such as upper limits on the number of resources used by the kernel, and to configure the internal kernel management data based on this. The amount of memory used by the kernel can be reduced by optimizing the kernel configuration to suit the user program. This also provides functions for statically registering user program modules such as interrupt handlers and the initial routine.

A definition statement used to register user program modules in the kernel configuration function is called a "static API".

When kernel configuration is executed, the configuration definition macros and static API are written in a text format file called the "configuration file", and the Configurator is executed with this as the input file.

Configurator takes the configuration file as the input file and outputs the kernel configuration file in the library format. The kernel configuration file must be linked with the user program when an object of the executable format is created.

See Section "5.2 Kernel Configuration" for details on how to execute the configurator and parameters during exection.

■ Configuration Definition Macros

The configuration definition macros are macros provided for user-defined kernel configurations. A list of the configuration definition macros is given below.

Table 3.13-1 List of Configuration Definition Macros

Function type	Name	Meaning	Range of values (default values shown in bold)
Priority definitions	_KERNEL_MAX_TSKPRI	Maximum task priority	**1** to 1024
	_KERNEL_INIT_TSKPRI	Initial task priority	**1** to 1024
	_KERNEL_MAX_SSYPRI	Maximum subsystem priority	**1** to 16
Function selection	_KERNEL_USE_TKDEFINT	Use or not use tk_def_int (1 means use)	**0** or 1
	_KERNEL_USE_IMALLOC	Use or not use the heap area (1 means use)	**0** or 1
	_KERNEL_USE_DEVT	Use or not use the device management functions (1 means use)	**0** or 1
	_KERNEL_REALMEMSZ	Size of the heap area	Any value (**0**)
Maximum number of each object	_KERNEL_MAX_TSK	Maximum number of tasks	**1** to 32767
	_KERNEL_MAX_SEM	Maximum number of semaphores	**0** to 32767
	_KERNEL_MAX_FLG	Maximum number of event flags	**0** to 32767
	_KERNEL_MAX_MBX	Maximum number of mailboxes	**0** to 32767
	_KERNEL_MAX_MTX	Maximum number of mutexes	**0** to 32767
	_KERNEL_MAX_MBF	Maximum number of message buffers	**0** to 32767
	_KERNEL_MAX_POR	Maximum number of rendezvous ports	**0** to 32767
	_KERNEL_MAX_MPF	Maximum number of fixed-size memory pool	**0** to 32767
	_KERNEL_MAX_MPL	Maximum number of variable-size memory pool	**0** to 32767
	_KERNEL_MAX_CYC	Maximum number of cyclic handlers	**0** to 32767
	_KERNEL_MAX_ALM	Maximum number of alarm handlers	**0** to 32767
	_KERNEL_MAX_SSY	Maximum number of subsystems	**0** to 255
	_KERNEL_MAX_REGDEV	Maximum number of registered devices	**0** to 255
	_KERNEL_MAX_OPNDEV	Maximum number of open devices	**0** to 255
	_KERNEL_MAX_REQDEV	Maximum number of device requests	**0** to 255
	_KERNEL_MAX_VCT	Maximum number of interrups	**16** to 256
Size specified	_KERNEL_SYS_STKSIZE	System stack size	**0x80** to 0xfffffffc
	_KERNEL_INIT_TSKSTKSZ	Initial task stack size	**0x80** to 0xfffffffc
	_KERNEL_DEVT_MBFSZ0	Message buffer size for event notification	**0** to 0xfffffffc
	_KERNEL_DEVT_MBFSZ1	Maximum message buffer size for event notification	**0** to 0xfffffffc

The value of "_KERNEL_MAX_TSKPRI" and the value of "_KERNEL_INIT_TSKPRI" must satisfy the following condition.

value of "_KERNEL_MAX_TSKPRI" ≥ value of "_KERNEL_INIT_TSKPRI"

The value of "_KERNEL_MAX_SEM" and the value of "_KERNEL_MAX_OPNDEV" must satisfy the following condition.

value of "_KERNEL_MAX_SEM" ≥ value of "_KERNEL_MAX_OPNDEV"

_KERNEL_REALMEMSZ specifies the size of the heap area. If the attribute of the TA_USERBUF is not specified upon creation of the task, the message buffer, or the memory pool, the task stack, the message buffer area, or the memory pool area can be automatically got from the heap area.

If the definition of any of the configuration definition macros is omitted, the minimum value that can be taken is selected as the default value. For example, if the definition of "_KERNEL_MAX_TSKPRI" is omitted, the maximum value of the task priority is set to 1. Similarly, if the definition of "_KERNEL_MAX_SEM" is omitted, the maximum number of semaphores is set to 0.

If the maximum number of an object is 0, that object cannot be used. For example, if the maximum number of semaphores is set to 0 and the user program contains semaphore-related system calls, an undefined error occurs for the semaphore-related system calls when the user system is built.

The configuration definition macros are written in the configuration file using the following syntax.

[Configuration Definition Macro Syntax]

Configuration definition macro   Defined value

Example)

```
_KERNEL_MAX_TSK            256
_KERNEL_INIT_TSKSTKSZ      0x1000
```

Notes:

- The maximum number of tasks defined by "_KERNEL_MAX_TSK" includes the initial task that is created within the kernel. Therefore, when the number of tasks that a user program creates is N, define the maximum number of tasks as (N+1) or more.
- Because the device management function uses the following objects, set the value for the maximum number of objects to "number used by user program + number used by device management".
  - Semaphores : One used for each device opened
  - Message buffers : One used by all device management functions
  - Event flags : One used by all device management functions

---

■ Static API

The interface for the user program modules that are statically defined by the Configurator is called the static API.

The static API can register the initialization routine, interrupt handlers, error routine, and power saving routine. Furthermore, interrupt handlers can also be registered from a user program using tk_def_int.

A list of the static API is shown in Table 3.13-2.

Table 3.13-2 List of Static API

Name	Function
ATT_INI	Defines the initial routine
DEF_INH	Defines an interrupt handler
VATT_ERR	Defines the error routine
VDEF_PSR	Defines a power saving routine

The static API is written in the configuration file using the following syntax.

[Static API Syntax]

- ATT_INI

  ATT_INI({Attributes, Extended Information, Entry address});

  Attributes:
  Specify TA_HLNG.

  Extended Information:
  This is ignored for the current version.

  Entry address:
  Specify the entry address of initial routine.

- DEF_INH

  DEF_INH(Interrupt Vector Number, {Attributes, Entry address});

  Interrupt Vector Number:
  A value from 0 to 255 can be specified. However, you cannot specify the number defined with "_KERNEL_MAX_VCT" or more. Furthermore, the interrupt numbers 0, 7 to 10, 13 and 14 are reserved by the system.

  Attributes:
  Specify TA_HLNG. Specify VTA_SRSV to specify the interrupt numbers reserved by the system.

  Entry address:
  Specify the entry address of interrupt handler.

- VATT_ERR

  VATT_ERR({Attributes, Entry address});

  Attributes:
  Specify TA_HLNG.

  Entry address:
  Specify the entry address of error routine.

- VDEF_PSR

  VDEF_PSR({Attributes, Entry address});

  Attributes:
  Specify TA_HLNG.

  Entry address:
  Specify the entry address of power saving routine.

  Example)

```
ATT_INI({ TA_HLNG, 0, uint});
DEF_INH(35, { TA_HLNG, inthdr});
VATT_ERR({TA_HLNG, uerr});
VDEF_PSR({TA_HLNG, pow_down});
```

■ Setting of Configuration

Define the following items at Kernel configuration function.

- Definition of the maximum number of objects

  Set the maximum value for the number of objects that the user program uses. The objects can be created up to this maximum value and used in the user program. Therefore, define the maximum value using a value bigger than the number of objects that are used in the user program.

  For example, when 3 semaphores are used in the user program, define the configuration specification macro "_KERNEL_MAX_SEM" as 3. In such a case, the program can operate without problems even it is defined as 10. However, since 10 semaphore control areas are ensured in kernel, the 7 unused control areas will become useless. Therefore, it is necessary to define the maximum number of objects used in application in order to optimize usage efficiency of memory.

  It is unnecessary to define objects not used in the user program.

  Table 3.13-3 displays number of bytes of memory consumed in kernel for each object.

Table 3.13-3 Consumed Memory of Object Management Block

Object name	Configuration specification macro	Management area size (byte)
Task	_KERNEL_MAX_TSK	106
Semaphore	_KERNEL_MAX_SEM	24
Event Flag	_KERNEL_MAX_FLG	20
Mailbox	_KERNEL_MAX_MBX	24
Mutex	_KERNEL_MAX_MTX	26
Message Buffer	_KERNEL_MAX_MBF	48
Rendezvous Port	_KERNEL_MAX_POR	32
Fixed-size Memory Pool	_KERNEL_MAX_MPF	44
Variable-size Memory Pool	_KERNEL_MAX_MPL	48
Cyclic Handler	_KERNEL_MAX_CYC	40
Alarm Handler	_KERNEL_MAX_ALM	36
Subsystem	_KERNEL_MAX_SSY	4
Device	_KERNEL_MAX_REGDEV	72
	_KERNEL_MAX_OPNDEV	68
	_KERNEL_MAX_REQDEV	50

For definition of maximum number of object, see "■ Configuration Definition Macros" in this section.

- Definition of priority maximum value

  Defines the maximum priority value of a task and subsystem. Similar to the maximum object value, when the value defined for the task priority becomes smaller, consumed memory of kernel can be reduced. When Task Priority is P, its consumed memory can be calculated according to following formula.

  Consumed Memory (byte) = $(8 \times P) + 4 \times (P / 32)$

- Definition of system stack size and stack size of the initial task

  Specifies the size of system stack and stack size of initial task. For specification method of these stack sizes, see "■ Configuration Definition Macros" in this section.

- Registration of the initial routine and error routine

  When using the initialization routine or error routine, perform the registration through the static API. For registration method of these routines, see "■ Configuration Definition Macros", "4.4 Initial Routine" in this section, and "4.9 Error Routine".

- Registration of an Interrupt Handler

  On using an interrupt handler, register it through a static API. After the system startup, dynamic registration of interrupt handler through tk_def_int is also available. In the case of dynamic registration, registration through a static API will be not necessary. In addition, in such a case, define "_KERNEL_USE_TKDEFINT" of configuration definition macro as 1.

  On using an interrupt vector table located in the ROM area, setting "_KERNEL_USE_TKDEFINT" to "0" will allow the kernel to cancel copying the vector table from the ROM to the RAM. Therefore, memory used by the kernel can be reduced.

  Whether to register an interrupt handler through a static API or tk_def_int is optional depending on processing of the user program. Registration through a static API has advantages in reducing the codes for operation of registration through tk_def_int.

CHAPTER 4
WRITING A USER PROGRAM

This chapter describes the basic items in writing a user program on µT-REALOS.

4.1 Configuring a User Program

This section explains how to configure a user program.

■ Configuring a User Program

A user program consists of the modules in Table 4.1-1. Build the user system after creating modules necessary for the user system.

Table 4.1-1 User Program Configuration Elements

Module name	Processing overview	Necessity
Reset entry routine	This routine is first launched by the hardware reset. It performs hardware initialization, and starts the kernel.	Mandatory
Initial routine	This routine is called from the kernel intialization. It provides the operating environment for the user program.	Mandatory
Task	Performs the main process of a user program.	Mandatory
Cyclic handler	Created when performing a process at regular time intervals.	Optional
Alarm handler	Created if there is a process to be performed after a certain time.	Optional
Interrupt handler	Created when handling hardware interrupts. When system time is used, it is necessary to create a timer interrupt handler.	Optional
Error routine	Created when handling kernel errors from a user program.	Optional
Power saving routine	Created when performing power saving process using a user program.	Optional
Extension SVC Handler	Created when defining user function using the extension SVC handler.	Optional
Device driver	Created when controlling the device driver using the device management API.	Optional

For more on these, see "4.3 Reset Entry Routine" to "4.12 Device Driver" in this document respectively.

4.2 Activation Flow

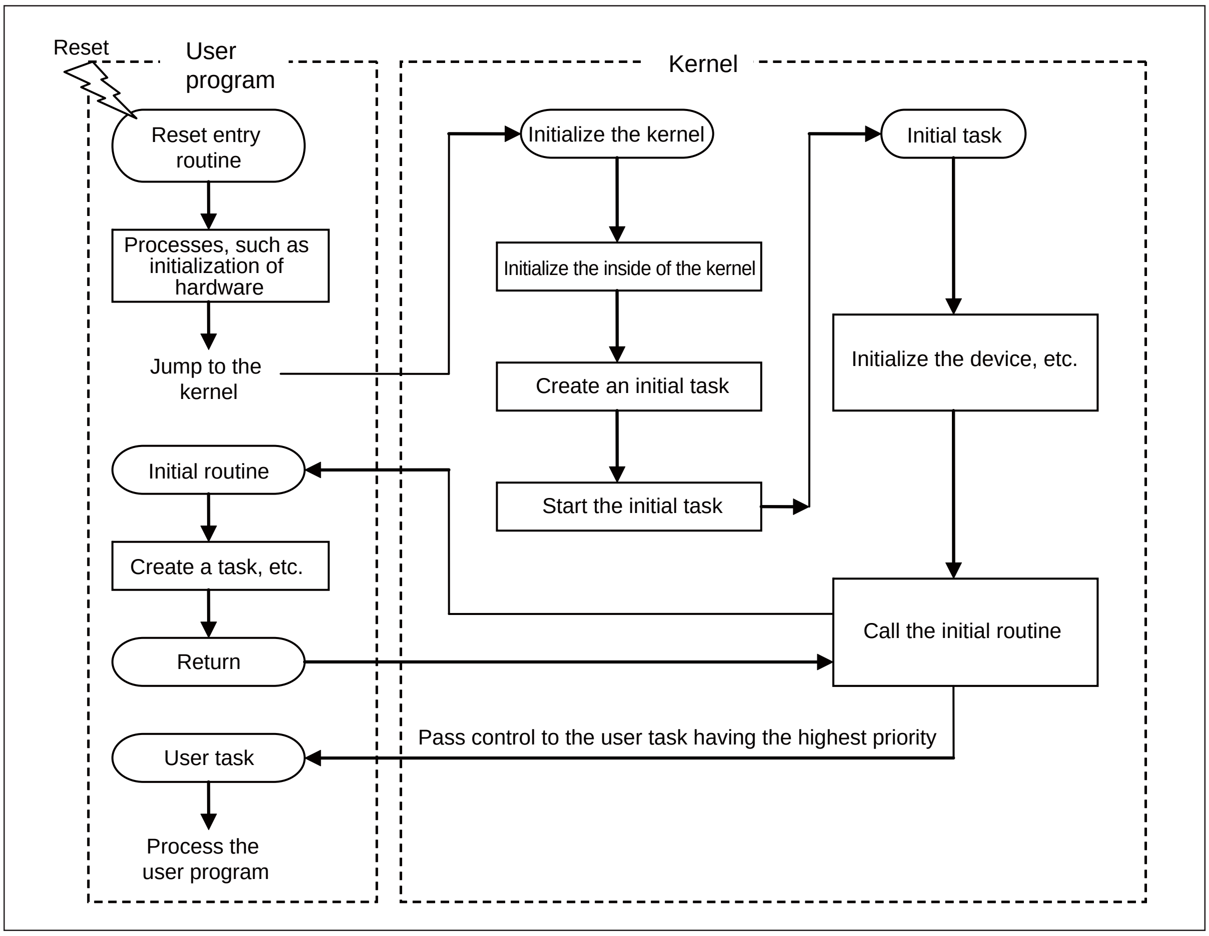
This section explains the process flow from the hardware reset occurrence until control is passed to the user program task.

■ Starting a User Program

Figure 4.2-1 shows the processing flow after hardware reset occurs.

When the initial routine of a user program is called by the initial task, control is passed to the user program having the highest priority task.

Figure 4.2-1 Start Flow



4.3 Reset Entry Routine

This section explains how to write the reset entry routine.

■ Reset Entry Routine

The reset entry routine, which is launched by reset, performs initialization of the processor and of the peripheral devices for which initial settings are necessary during reset. Control is then moved to µT-REALOS.

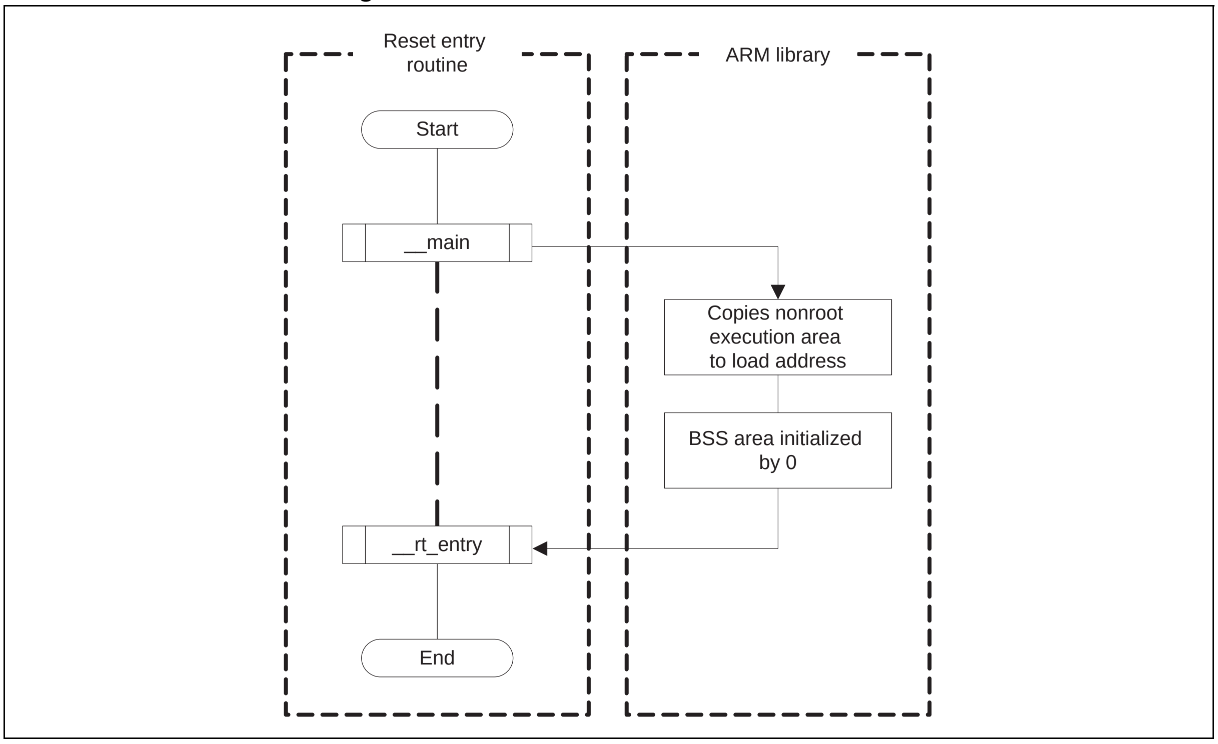
■ Process of Reset Entry Routine

The reset entry routine generally performs the following processes:

- Initializing the data area (the ARM library) (mandatory)
  Calls __main function of the C library and performs the following processing.

1. Copies nonroot (Read Only and Read Write) execution areas into each load address.
2. BSS (Block Started by Symbol) area is initialized by 0.
3. Branches into __rt_entry.

Figure 4.3-1 Initialization Flow in Data Area


Reset entry routine
ARM library
Start
__main
Copies nonroot execution area to load address
BSS area initialized by 0
__rt_entry
End

- Setting the privileged mode, MSP (mandatory)

  Performs the following processing.

  1. Sets the privileged mode.
  2. Sets the main stack address used while the kernel and the exception handler are operating to the MSP register.

- Starting the kernel (mandatory)

  Starts the kernel, allowing it to jump to the label of "knl_start_main" by the BX command of the assembly language.

■ A specific Example of the Reset Entry Routine

The description examples for each process of the reset entry routine are shown below. The source codes are attached to the product as a sample program (icrt0.asm) of µT-REALOS.

- Initializing the data area (the ARM library)

  Calls the main function and initializes the data area. Initialization processing of the ARM library is not performed in the following description example. See "ARM Developer Suite Compiler and Library Guide" of ARM for details on __main function processing.

Figure 4.3-2 Description Example of Initializing the Data Area (the ARM Library)

```
        ;; -------------------------------------------
        ;; Copy R0/RW area
        ;; Initialize ZI(BSS) area
        ;; -------------------------------------------
        IMPORT  __main
        B       __main

        EXPORT  __rt_entry
__rt_entry
```

- Setting the privileged mode, MSP

  In the following example, the mode is set as the privileged mode (µT-REALOS always operates in the privileged mode), and the address of the main stack is set in the MSP register.

Figure 4.3-3 Description Example of Setting the privileged mode, MSP

```
;; -------------------------------------------
;;  MSP setting
;; -------------------------------------------
mov     r0, #0                       ; Use MSP stack (privileged mode)
msr     control, r0
isb

ldr     r0, =_kernel_MSP_stack_top  ;  Set main stack address
msr     msp, r0
```

- Starting the kernel

  Jumps to the label of "knl_start_main" to start the kernel.

Figure 4.3-4 Description Example of Starting the kernel

```
;; -------------------------------------------
;;  Initialize kernel
;; -------------------------------------------
IMPORT knl_start_main
ldr     ip, = knl_start_main
mov     r0, #0
bx      ip
```

4.4 Initial Routine

This section explains how to write the initialization routine.

■ Process of the Initial Routine

The initial routine is called from the initial task created during initialization of the kernel. Although the initial routine can be described freely in accordance with the user program, it generally performs the following processes:

- Creating and starting objects necessary for operations of the user program, such as tasks, semaphores, time event handlers
- Initializing and registering device drivers
- Initializing hardware
- Starting a timer interrupt

Note:

The initial routine is executed while the interrupt is enabled.

■ Description Format of the Initial Routine

The initial routine is described as follows:

Figure 4.4-1 Description Format of the Initial Routine

```
void sample_init(void)
{
        /*
           Process the initial routine
          */
        return;
}
```

■ Description Example of the Initial Routine

Figure 4.4-2 shows the description example of the initial routine. The source codes are attached to the product as a sample program (init_task.c) of µT-REALOS.

In the following example, after the timer for the system clock is started (SysTick_init()), semaphore and three tasks (task ID=tsk1, tsk2, tsk3) are created. Then, the created three tasks are started.

Figure 4.4-2 Description Example of the Initialization Routine

```
void uinit_task(void)
{
        ID tsk1
        ID tsk2
        ID tsk3
        T_CTSK ctsk;
        T_CSEM csem;
        static INT task1_stack[0x400/4];
        static INT task2_stack[0x400/4];
        static INT task3_stack[0x400/4];

        /*symtem clock set*/
        SysTick_init();

        csem.sematr     = TA_TFIFO | TA_FIRST;
        csem.isemcnt    = 0;
        csem.maxsem     = 1;
        sem1 = tk_cre_sem(&csem);           /* Create semaphore */

        ctsk.exinf      = (VP)1;
        ctsk.tskatr     = TA_HLNG | TA_USERBUF;
        ctsk.task       = task1;
        ctsk.itskpri    = 1;
        ctsk.stksz      = (W)sizeof(task1_stack);
        ctsk.bufptr     = task1_stack;
        tsk1 = tk_cre_tsk(&ctsk);           /* Create task1 */

        ctsk.exinf      = (VP)2;
        ctsk.tskatr     = TA_HLNG | TA_USERBUF;
        ctsk.task       = task1;
        ctsk.itskpri    = 2;
        ctsk.stksz      = (W)sizeof(task2_stack);
        ctsk.bufptr     = task2_stack;
        tsk2 = tk_cre_tsk(&ctsk);           /* Create task2 */

        ctsk.exinf      = (VP)3;
        ctsk.tskatr     = TA_HLNG | TA_USERBUF;
        ctsk.task       = task2;
        ctsk.itskpri    = 3;
        ctsk.stksz      = (W)sizeof(task3_stack);
        ctsk.bufptr     = task3_stack;
        tsk 3 = tk_cre_tsk(&ctsk);          /* Create task3 */

        tk_sta_tsk(tsk1, 1);                /* Start task1 */
        tk_sta_tsk(tsk2, 2);                /* Start task2 */
        tk_sta_tsk(tsk3, 3);                /* Start task3 */
}
```

4.5 Task

This section explains how to write a task.

■ Description Format of the Task

The task is described as follows:

Figure 4.5-1 Description Format of the Task

```
void task(INT stacd, VP exinf)
{
        /*
          Process the body of the task program
          */
        tk_ext_tsk(); or tk_exd_tsk(); /* Task termination */
}
```

The following values are passed to dummy parameters stacd and exinf respectively.

stacd: The task start code specified during task startup (tk_sta_tsk).

exinf: The extension information specified when the task is created (tk_cre_tsk).

A function(task) cannot be terminated by a simple return. Using tk_ext_tsk or tk_exd_tsk to ensure termination.

■ Creating a Task

tk_cre_tsk is called to create a task. In the following example, function, "task1", is being created using task priority 1. If tk_cre_tsk is terminated normally, the task ID will be returned as the return value.

Figure 4.5-2 Description Example of Task Creation

```
ID tid1;                    /* Task ID of task1 */
T_CTSK ctsk;                /* Input parameter of tk_cre_tsk */
INT task1_stack[256];       /* Stack area of the task */


ctsk.exinf   = (VP)1;                    /* Extension information=1 */
ctsk.tskatr  = TA_HLNG | TA_USERBUF;  /* Attribute */
ctsk.task    = task1;                    /* Start address of the task */
ctsk.itskpri = 1;                        /* Task priority */
ctsk.stksz   = (W)sizeof(task1_stack);  /* Stack size */
ctsk.bufptr  = task1_stack;              /* Start address of the stack */
tid1   = tk_cre_tsk(&ctsk);              /* Create the task */
```

For details of tk_cre_tsk, see "3.3.1 tk_cre_tsk" of "API Reference" .

■ Starting a Task

A task created by tk_cre_tsk is initially in the stop status. Therefore, tk_sta_tsk is called to run this task. In the example below, the task whose task ID is tid1 is being started.

Figure 4.5-3 Description Example of the Task Startup

```
tk_sta_tsk(tid1, 1);          /* Start the task whose task ID is tid1 */
```

The status of a task started by tk_sta_tsk is executable. If the priority of a task is higher than those of other tasks of execution status or executable status, the task attains execution status.

For details of tk_sta_tsk, see "3.3.3 tk_sta_tsk" of "API Reference".

■ A specific Example of the Task

Figure 4.5-4 shows the description example of a task, and Figure 4.5-5 shows the operation diagram of the program in the description example. The source codes are attached to the product as a sample program (init_task.c) of µT-REALOS. In addition, the task in this specific example is created/started using the initial routine given in Figure 4.4-2.

In Figure 4.5-4, task1 and task2 move to the status of waiting for the semaphore of sem1 by tk_wai_sem. task3 releases the semaphore resources of sem1 by the system call of tk_sig_sem. This releases task1 and task2 from the waiting status. The task priorities are: task1 > task2 > task3.

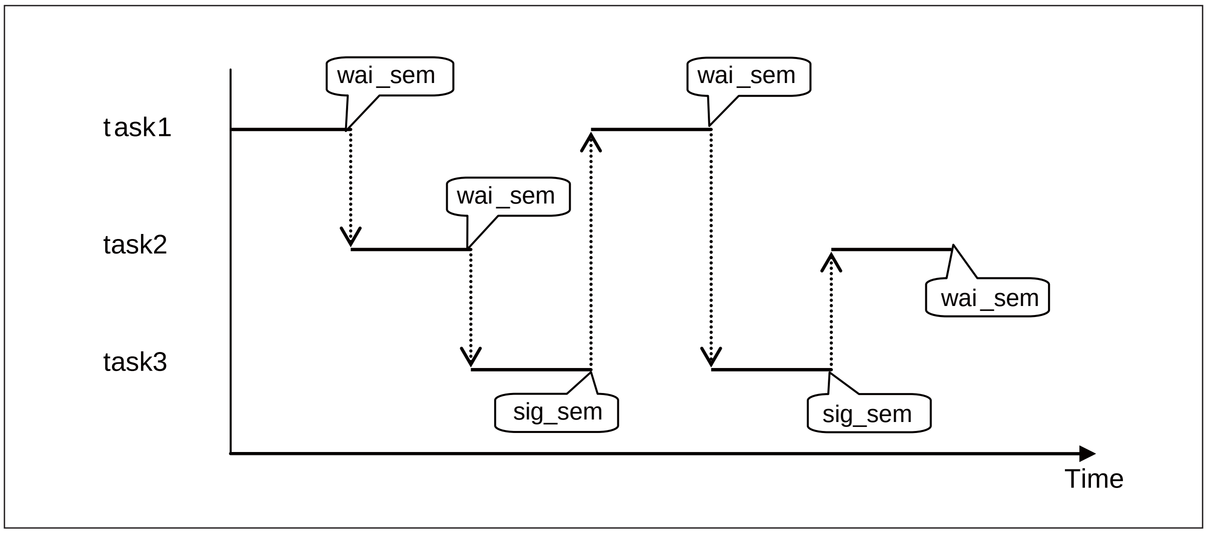
Figure 4.5-4 Description Example of a Task

```
static void task1( INT stacd, VP exinf )
{
        if(stacd == 1){
                while (1) {
                        tk_wai_sem(sem1, 1, TMO_FEVR);
                }
        }
        else{
                tk_ext_tsk();        /* Exit task */
        }
}

static void task2( INT stacd, VP exinf )
{
        if(stacd ==     2){
                while (1) {
                        tk_wai_sem(sem1, 1, TMO_FEVR);
                }
        }
        else{
                tk_ext_tsk();        /* Exit task */
        }
}

static void task3( INT stacd, VP exinf )
{
        if (stacd == 3){
                while (1) {
                        tk_sig_sem(sem1, 1);
                }
        }
        else{
                tk_ext_tsk();        /* Exit task */
        }
}
```

Figure 4.5-5 Operation Diagram of the Description Example



Note:

While dispatch is on hold, the state transition is delayed until the state enters into where dispatch occurs, when moving the tasks during execution to the forcible waiting state and the stop state. In such a case, although tasks being executed will retain the execution status, the processing of transition to the forcible waiting state or the stop state is already being executed.

4.6 Cyclic Handler

This section explains how to write a Cyclic handler.

■ Description Format of a Cyclic Handler

The cyclic handler is described as follows:

Figure 4.6-1 Description Example of a Cyclic Handler

```
void cychdr1(VP exinf)
{
    /* Process the Cyclic handler */

    return; /* Terminate the Cyclic handler */
}
```

■ Creation of a Cyclic Handler

tk_cre_cyc is called to create a cyclic handler. In the example below, a cyclic handler with the start period of 1 second (1000ms) for the function "cychdr1" is created. When creation of a cyclic handler normally ends, the cyclic handler ID is returned as the return value.

Figure 4.6-2 Description Example of the Cyclic Handler Creation

```
ID cycid1;                              /* Cyclic handler ID */
T_CCYC ccyc;                            /* Input parameter of tk_cre_cyc*/
ccycexinf     = (VP)1;                  /* Extension information=1 */
ccyc.cycatr   = TA_HLNG | TA_STA;       /* Attribute */
ccyc.cychdr   = cychdr1;                /* Start address of the Cyclic handler */
ccyc.cyctim   = 1000;                   /* Start Cyclic */
ccyc.cycphs   = 0;                      /* Start phase */
cycid1 = tk_cre_cyc(&ccyc);             /* Create the Cyclic handler */
```

When specifying TA_STA for attribute, a cyclic handler becomes the action status after it was created. After the start period elapses, a cyclic handler is called. If not specifying TA_STA, a cyclic handler becomes the stop status after it was created.

Specifying TA_HLNG for attribute indicates the target cyclic handler is written in C. Be sure to specify TA_HLNG.

■ Launch of a Cyclic Handler

A Cyclic handler is moved from the stop status to the action status, when tk_sta_cyc is called. In the following example, the cyclic handler is started as the Cyclic handler ID of cycid1.

Figure 4.6-3 Description Example of the Cyclic Handler Startup

```
tk_sta_cyc(cycid1);   /* Start the Cyclic handler whose ID is cycid1 */
```

4.7 Alarm Handler

This section explains how to write an alarm handler.

■ Description Format of an Alarm Handler

An alarm handler is described as follows:

Figure 4.7-1 Description Example of an Alarm Handler

```
void almhdr1(VP exinf)
{
    /* Process the alarm handler */
    return; /* Terminate the alarm handler */
}
```

The extension information specified when an alarm handler is created (tk_cre_alm) is passed to exinf.

■ Creating an Alarm Handler

tk_cre_alm is called to create an alarm handler. In the following example, function "almhdr1" is created as an alarm handler. If creation of an alarm handler is terminated normally, the alarm handler ID will be returned as the return value.

An alarm handler moves to the stop status after it is created.

Figure 4.7-2 Description Example of the Alarm Handler Creation

```
ID almid1;                  /* Alarm handler ID*/
T_CALM calm;                /* Input parameter of tk_cre_alm*/

calm.exinf   = (VP)1;              /*Extension information =1 */
calm.almatr  = TA_HLNG;            /* Attribute */
calm.almhdr  = almhdr1;            /* Start address of the alarm handler */
almid1 = tk_cre_alm(&calm);        /* Create the alarm handler */
```

■ Starting an Alarm Handler

An alarm handler is moved from the stop status to the action status, when tk_sta_alm is called. The following example activates Alarm Handler ID:almid1 in 100ms.

Figure 4.7-3 Description Example of the Alarm Handler Startup

```
tk_sta_alm(almid1, 100);  /* activates Alarm Handler ID:
                             almid1 in 100ms. */
```

4.8 Interrupt Handler

This section explains how to write an interrupt handler.

■ Description Format of an Interrupt Handler

An interrupt handler is described as follows:

Figure 4.8-1 Description Example of an Interrupt Handler

```
void sample_inthdr(   void)
{
  /* Interrupt handler body */
}
```

The interrupt handler is executed at the task independent portion. In addition, it is started while interrupt is enabled. Therefore, while an interrupt handler is being executed, the interrupt handler may be started multiply. For details, see "CHAPTER 5 EXCEPTION" of "Cortex-M3 Technical Reference Manual".

Note:

To activate the interrupt handler, a 32-byte stack is automatically consumed for each 1-level interrupt. Bear this in mind when you are to design the system stack size.

■ Registering an Interrupt Handler

An interrupt handler can be registered in the following two ways.

- Register an interrupt handler during kernel configuration using static API "DEF_INH". To perform operations with the vector table placed in the ROM, register an interrupt handler using static API.

  In the example below, the timer interrupt handler of vector number 15 "SysTick_Handler" is registered as an interrupt handler.

Figure 4.8-2 Example of Registering an Interrupt Handler Using Static API

```
DEF_INH(15, {TA_HLNG|VTA_SRSV, SysTick_Handler });
```

- Call tk_def_int from a user program to dynamically register an interrupt handler.

  Before executing kernel configuration, set "_KERNEL_USE_TKDEFINT" of the configurator specification macro to 1.

  In the example below, the timer interrupt handler of vector number 15 "SysTick_Handler" is registered as an interrupt handler.

Figure 4.8-3 Example of Registering an Interrupt Handler Through a User Program

```
T_DINT dint;
ER err;

dint.intatr  = TA_HLNG|;            /* Attribute */
dint.inthdr = SysTick_Handler;  /* Start address of the interrupt handler */
err = tk_def_int(15, &dint);        /* Register the interrupt handler */
```

■ Timer Interrupt Handler

To use the functions of time event handler, timeout, and system time, it is necessary to let the timer interrupt occur at intervals of 1ms, and then update the system time using the interrupt handler. System time will be updated when isig_tim is called.

A sample program (init_task.c) included with μT-REALOS uses system exception SysTick timer for the timer interrupt handler.

An example of the timer interrupt is shown below.

Figure 4.8-4 Description Example of an Timer Interrupt Handler

```
EXPORT void SysTick (void)
{
        /*
        Clear the timer interrupt factors
        */
        isig_tim();
}
```

Notes:

- When an interrupt handler is described using assembler, note the following points:
  - Calling an interrupt handler or returning from an interrupt handler is not via the OS.
  - As the OS does not back up and restore registers or perform stack settings, perform such processes on the interrupt handler side.
- A time event handler is executed according to the interrupt priority of an interrupt handler for system clock calling isig_tim.
- As the SysTick timer stops while the standby mode is set, neither time event handler activation nor system time increment is not performed.
  See "4.10 Power Saving Routine" for details on SysTick timer operation while the power saving mode is set.

4.9 Error Routine

This section explains how to write an error routine.

■ Description Format of an Error Routine

The description format of an error routine is shown as follows:

Figure 4.9-1 Description Format of an Error Routine

```
void sample_errrtn (UINT errptn, INT errinf1,INT errinf2)
{
        /* Error routine body */
}
```

The kernel sets the following information to errptn, errinf1, and errinf2 and calls them.

- errptn : Error factor
  = _KERNEL_ERR_SYS_DOWN (0x01): System down
  = _KERNEL_ERR_INI_ERR (0x02): Initial setting error
  = _KERNEL_ERR_EIT_DOWN (0x04): Undefined interrupt
- errinf1 : Error information1
  In the case of [_KERNEL_ERR_SYS_DOWN]
  = 0x1 : tk_ext_tsk was called from the task independent portion.
  = 0x2 : tk_exd_tsk was called from the task independent portion.
  = 0x3 : tk_ext_tsk had been called while dispatch was disabled.
  = 0x4 : tk_exd_tsk had been called while dispatch was disabled.
  In the case of [_KERNEL_ERR_INI_ERR]
  Initial setting error information
  = 0x1 : Heap area assignment error
  = 0x2 : System startup error
  = 0x3 : Initial task startup error
  = 0x4 : Module initialization error
  = 0x5 : Power off processing error
  In the case of [_KERNEL_ERR_EIT_DOWN]
  Uncertain value
- errinf2 : Error information2
  Not used. Reserved for future extension.

■ Registering an Error Routine

For registering an error routine, see "3.13 Kernel Configuration Function".

4.10 Power Saving Routine

This section explains how to write a power saving routine.

■ Description Format of a Power Saving Routine

The power saving routine is a process called when the status has become idle inside the kernel. The processing of transition to the power saving mode is described inside a function.

A power saving routine is described as follows:

Figure 4.10-1 Description Example of a Power Saving Routine

```
void  usr_low_pow ( void )
{
      /* Describe the process of transition to the power saving mode*/
}
```

Notes:

- The FM3 Family supports the following three power saving modes.
  - SLEEP
  - TIMER
  - STOP
- While TIMER and STOP modes are operating, the SysTick timer also stops.
- See "CHAPTER 5 LOW POWER CONSUMPTION MODE" of "MB9Axxx/MB9Bxxx Series Peripheral Manual" for details on the power saving modes.

■ Registering a Power Saving Routine

For registering a power saving routine, see "■ Static API" in "3.13 Kernel Configuration Function".

Note:

When a system call is made inside the power saving routine, the operation is not guaranteed.

4.11 Extension SVC Handler

This section explains how to create and call an extension SVC handler.

■ Description Format of an Extension SVC Handler

An extension SVC handler is described as follows:

Figure 4.11-1 Description Format of an Extension SVC Handler

```
INT svchdr(VP pk_para, FN fncd)
{
        /*
          Branch and proceed according to fncd
        */
        return retcode; /*Terminate the extension SVC handler */
}
```

The following values are passed to parameters pk_para and fncd respectively.

pk_para :	Turns the parameters passed from the caller into the packet format. The packet format can be determined by a user who creates subsystems arbitrarily.
fncd :	A function code which contains the subsystem ID in its lower 8 bits. The remaining higher bits are determined by a user who creates subsystems arbitrarily.

■ Calling Format of an Expansion SVC Handler

An extension SVC handler is called from call_EX_SVC function in a user program. An extension SVC handler with an ID specified by fncd is called. It is described as follows:

Figure 4.11-2 Calling Format of an Expansion SVC Handler

```
call_EX_SVC(VP pk_para , FN fncd);
```

In the example below, the SVC handler whose subsystem ID (sayid) is 10 is called. In the called extension SVC handler, the beginning addresses of packets containing arg1 and arg2 are passed to pk_para, and "0x10A" is passed to fncd.

Figure 4.11-3 Example of Calling an Expansion SVC Handler

```
#define FUNC1_FNCD  0x10A   /* ssyid = 10 */
INT func1(int arg1, int arg2)
{
        int para[2];
        para[0]=arg1;
        para[1]=arg2;
        call_EX_SVC(&para , FUNC1_FNCD);
}
```

4.12 Device Driver

This section explains how to write a device driver.

■ Device Driver Interface

In the µT-Kernel specification, the device management function increases the portability of the device drivers by unifying their interfaces. The following describes how to create a driver based on the device driver interface. For details of a device driver, see "CHAPTER 4 DEVICE DRIVER INTERFACE" of "API Reference".

■ Determining A Device Name

Device name is the name granted to the type unit of a device using up to 8 bytes.

A device name using the following format:.

Figure 4.12-1 Format of a Device Name

Type	Unit	Sub unit

A device name consists of the following elements.

Type :	A name indicating the type of a device. Characters that can be used are a-z, A-Z.
Unit :	A number indicating the physical device. Characters that can be used are a-z. Specified using a single character. Assigned for each unit starting with a.
Sub unit :	A number indicating the logical device. Characters that can be used are numbers between 0-254, not exceeding 3 digits. Assigned for each sub unit starting with 0.

■ Creating an Open Function (openfn)

An open function is called from the kernel when tk_opn_dev is called from a user program. An open function makes preparation to access the device data.

For details of an open function, see "● Open function (openfn)" of Section "4.11 Device Processing Function" in "API Reference".

Figure 4.12-2 Description Format of Open Function (openfn)

```
ER ercd = openfn(ID devid, UINT omode, VP exinf)
{
            /*
            Device open processing
            */
}
```

■ Creating a Close Function (closefn)

A close function is called from the kernel when tk_cls_dev is called from a user program.

Calling a close function means access to a device has been terminated. The driver then performs the device terminating process whenever necessary.

For details of a close function, see "● Close function (closefn)" of Section "4.11 Device Processing Function" in "API Reference".

Figure 4.12-3 Description Format of Close Function (closefn)

```
ER ercd = closefn(ID devid, UINT option, VP exinf)
{
        /*
        Device close processing
        */
}
```

■ Creating an Execute Start Function (execfn)

An execute start function is called from the kernel when tk_rea_dev, tk_srea_dev, tk_wri_dev, or tk_swri_dev is called from a user program.

An execute start function is called when the data to be processed is set to the parameter. However, the function does not return upon completion of the data process, instead it returns when the process has been accepted. For example, when the data to be written to a device is passed via tk_wri_dev, it returns on completion of the write start instruction to a device, and it is not necessary to wait for completion of the device write process.

For details of an execute start function, see "● Execute start function (execfn)" of Section "4.11 Device Processing Function" in "API Reference".

Figure 4.12-4 Description Format of Execute Start Function (execfn)

```
ER ercd = execfn(T_DEVREQ *devreq, TMO tmout, VP exinf)
{
        /*
        Device process start
        */
}
```

■ Creating a Wait Completion Function (waitfn)

A wait completion function is called from the kernel when tk_wai_dev, tk_srea_dev, or tk_swri_dev is called from a user program.

A wait completion function waits for the completion of I/O requests accepted at the process start function. Therefore, a waiting for completion function may use an API function (such as tk_slp_tsk) which enters the waiting status, as it waits for completion of hardware.

For details of a wait completion function, see "● Wait completion function (waitfn)" of Section "4.11 Device Processing Function" in "API Reference".

Figure 4.12-5 Description Format of Wait Completion Function (waitfn)

```
INT pktno = waitfn(T_DEVREQ *devreq, INT nreq, TMO tmout, VP exinf)
{
            /*
            Device wait for completion process
            */
}
```

■ Creating an Abort Execute Function (abortfn)

An abort execute function is called from the kernel if there are unfinished I/O requests left in the device when the device close instruction is issued from a user program.

An abort execute function aborts a process of I/O requests specified by parameters. It forces the device to abort I/O, and removes the waiting state if the task has entered a state waiting for I/O completion.

For details of an abort execute function, see "● Abort execute function (abortfn)" of Section "4.11 Device Processing Function" in "API Reference".

Figure 4.12-6 Description Format of Abort Execute Function (abortfn)

```
INT pktno = waitfn(T_DEVREQ *devreq, INT nreq, TMO tmout, VP exinf)
{
            /*
            Device process abort
            */
}
```

■ Creating an Event Function (eventfn)

An event function is called from the kernel when tk_sus_dev or tk_evt_dev is called from a user program. This function is called from a user program or the kernel when notifying a device of some event.

As an event function passes an event type to a parameter, the driver performs process for that event.

For details of an event function, see "● Event function (eventfn)" of Section "4.11 Device Processing Function" in "API Reference".

Figure 4.12-7 Description Format of Event Function (eventfn)

```
INT rtncd = eventfn(INT evttyp, INT evtinf, VP exinf)
{
            /*
            Device event process
            */
}
```

4.13 Notes when Writing a User Program

This section explains notes when writing a user program of µT-REALOS.

■ Notes on the Overall of a Program

- Internal identifiers starting with "_KERNEL", "_kernel", "tk_", "tm_"and "knl_"

  The kernel of µT-REALOS uses symbols and macros starting with the above mentioned. Do not use these symbols and macros in a user program. This may cause duplicate definition.
- Management register of µT-REALOS

  The CONTROL register is managed by µT-REALOS. Do not change this register by a user program.
- Include file of kernel

  Include "(µT-REALOS Install Directory)\utkernel\7-M\include\tk\tkernel.h" in a user program using a system call.

■ Notes on the Overall of a System Call

- A system call can be made while the task independent portion or dispatch is disable.

  When calling is disabled, an E_CTX error or exception may occur. For availability of calling, see "3.1 System Call List" of "API Reference" in addition, operations cannot be guaranteed when isig_tim or tk_ret_int is called from the task section.
- Omitting the error check of a system call

  Check for entry address and packet address will not be performed. Specifying an illegal address may cause an abnormal operation.

CHAPTER 5 HOW TO CONSTRUCT A SYSTEM

This chapter explains how to construct a user system.

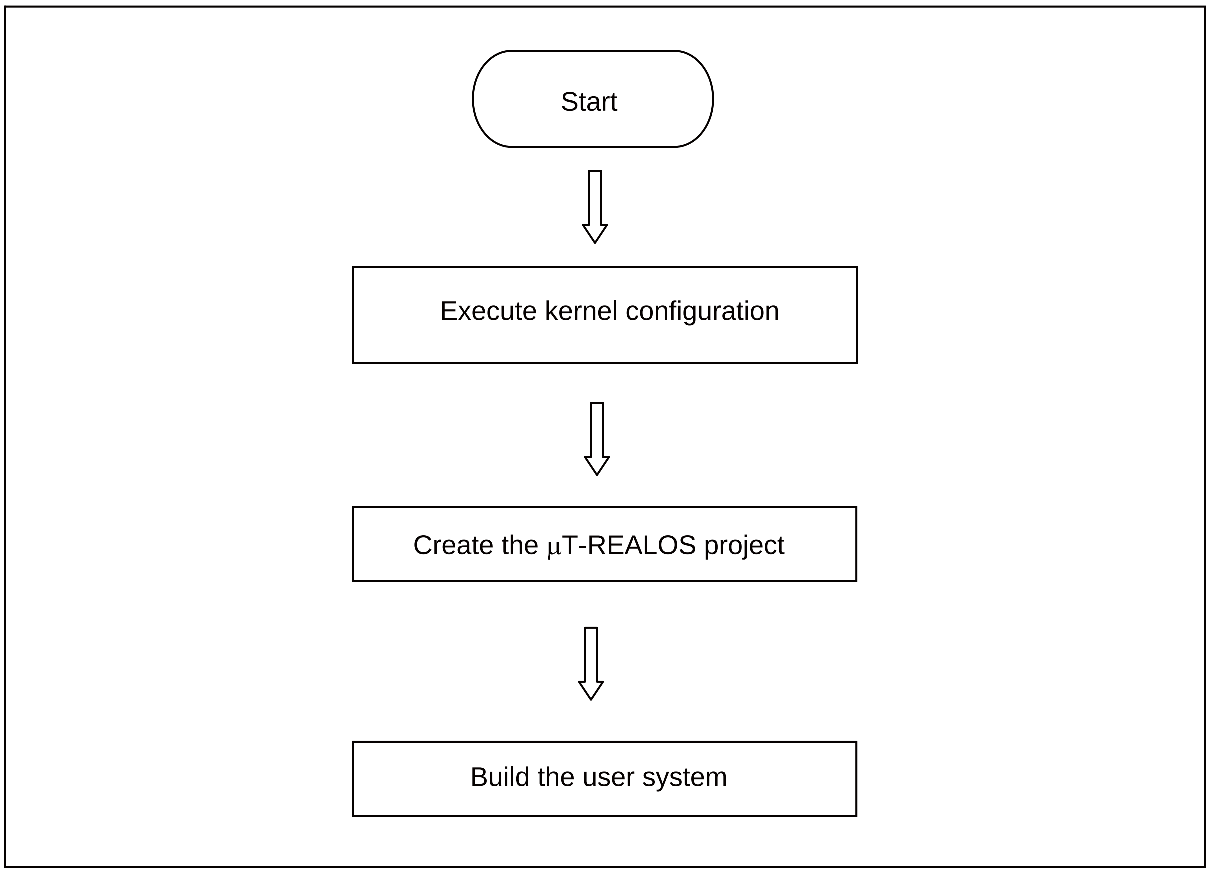
5.1 Steps of Constructing a System

This section explains steps of constructing a system including compiling, and kernel configuration of a user program for μT-REALOS.

■ Steps of System Construction

Construct the user system of μT-REALOS using the following steps.

Figure 5.1-1 Steps of Constructing a System



5.2 Kernel Configuration

This section explains how to execute kernel configuration and create a kernel configuration file.

■ Setting Environment Variables

Set directories suited for the following environment variables in order to use the configurator.

Table 5.2-1 Environment Variables Used for the Configurator

Environment variable	Directory
RTOS	(µT-REALOS Install Directory)
PATH	(µT-REALOS Install Directory) \bin
PATH	Add directory for storing the following RVDS tools armcc: C compiler armasm: Assembler armar: Librarian

■ Starting the Configurator

The configurator (ftcfs.exe) is stored in the "bin" directory under the µT-REALOS installation directory. Start the configurator manually or from a batch procedure in the following syntax to create a kernel configuration file.

For details of descriptive content of a configuration file, see "3.13 Kernel Configuration Function".

```
ftcfs -f file_name -cpu cpu_name -out path [ -V ] [ -g ] [ -help ] [ -noeit ] -RVDS
```

Table 5.2-2 Startup Options for the Configurator

Option name	Description
-f file_name	Specifies the configuration file name as the file_name. This parameter cannot be omitted.
-cpu cpu_name	Specifies the target CPU (MB number). "CM3" can be specified for the FM3 family in general. This parameter cannot be omitted.
-out path	Specifies the output directory for the kernel configuration file that is output by the configurator as "path". This parameter cannot be omitted.
-V	Outputs the configurator startup message.
-g	Outputs debugging information.
-help	Displays Help.
-noeit	Does not incorporate a vector table into the kernel configuration file that is finally output by the configurator. A vector table file is output as "eit_vector.s".
-RVDS	Uses ARM tools (RVDS). This parameter cannot be omitted.

- Startup example

```
ftcfs -f C:\ut_realos\utkernel\7-M\smpsys\smpsys.tcf -cpu CM3 -out C:\ut_realos\utkernel\7-
M\smpsys -RVDS
```

Notes:

- When configuration is executed, a file is created temporarily in the directory defined by the environment variable TMP.
- A sample configuration file is stored in the following directory.
  (µT-REALOS Install Directory)\utkernel\7-M\smpsys\smpsys.tcf
- Options inside the [] may be omitted.

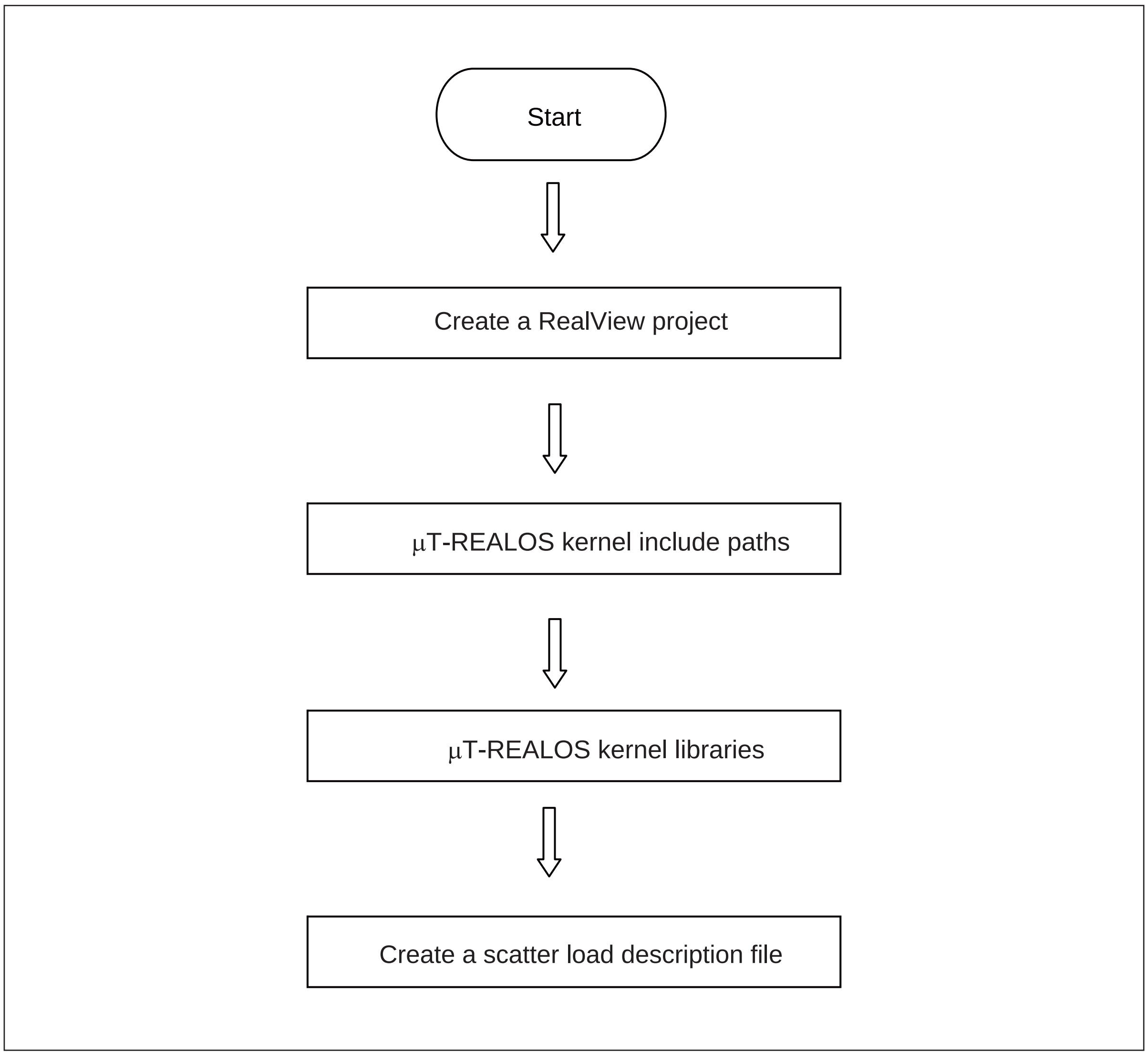
5.3 Create the µT-REALOS Project

This section describes how to create the µT-REALOS Project on ARM Workbench IDE.

■ Steps for Creating the µT-REALOS Project

Create the µT-REALOS project using the following steps.

Figure 5.3-1 Steps for Creating the µT-REALOS Project


Start
Create a RealView project
µT-REALOS kernel include paths
µT-REALOS kernel libraries
Create a scatter load description file

■ Sample Program of µT-REALOS

A sample program of µT-REALOS is stored in the following directory.

(µT-REALOS Install Directory)\utkernel\7-M\smpsys

If you wish to create a new µT-REALOS project, see the following descriptions in this chapter.

■ Create a µT-REALOS Project

Steps for creating a µT-REALOS project using the ARM Workbench IDE are shown below.

(1) Create a RealView project

Start the ARM Workbench IDE to create a RealView project and add a user file. For details of how to create a RealView project and add a file, see "ARM Workbench IDE User Manual".

(2) Set µT-REALOS kernel include paths

In order to use µT-REALOS functions, set the following directory include paths for a RealVeiw project.

(µT-REALOS Install Directory)\utkernel\7-M\kernel\tkernel\src

(µT-REALOS Install Directory)\utkernel\7-M\kernel\tstdlib

(µT-REALOS Install Directory)\utkernel\7-M\kernel\sysdepend\cpu\fm3

(µT-REALOS Install Directory)\utkernel\7-M\kernel\sysdepend\device\app_fm3

(µT-REALOS Install Directory)\utkernel\7-M\include

Set the include paths as follows:

1. Select "Project -> Properties" in the ARM Workbench IDE menu.
2. Select "C/C++ General -> Settings" in the tree.
3. Select "ARM RealView Compiler 4.0 -> Directory" on the Tool Settings tab.
4. Push "Add" for a user include path. After the path is added, push "OK". Add all the paths.
5. Select "ARM RealView Assembler 4.0 -> Directory" on the Tool Settings tab.
6. Push "Add" for a user include path. After the path is added, push "OK" to add all the paths.

(3) Add µT-REALOS kernel libraries

In order to use µT-REALOS functions, add the following libraries to the RealView project.

(µT-REALOS Install Directory)\utkernel\7-M\lib\build\app_fm3\libtm.a

(µT-REALOS Install Directory)\utkernel\7-M\lib\build\app_fm3\libstr.a

(µT-REALOS Install Directory)\utkernel\7-M\lib\build\app_fm3\libtk.a

(µT-REALOS Install Directory)\utkernel\7-M\kernel\tkernel\build\app_fm3\libtkernel.a

(µT-REALOS Install Directory)\utkernel\7-M\kernel\sysmain\build\app_fm3\libtstdlib.a

Kernel configuration file
(for example: (µT-REALOS Install Directory)\utkernel\7-M\smpsys\config.a)
(Kernel configuration file config.a is a library created in the configurator.)

For details on how to add libraries, see "ARM Workbench IDE User Manual".

(4) Create a scatter load description file

Create a scatter load description file using the scatter file editor of the ARM Workbench IDE. For details, see "ARM Workbench IDE User Manual".

Section names used by the kernel are listed below:

Table 5.3-1 Kernel Specific Section List

Type	Section name	Meaning
Code	_kernel_code_sc	Kernel code
Code	_kernel_eit_sc	Vector table
Data	_kernel_const_sc	Kernel constant data
Data	_kernel_sysinfo_sc	Control block
Data	_kernel_data_sc	Kernel data
Data	_kernel_heap_sc	Kernel heap
Zero	_kernel_sstack_sc	System stack

5.4 Build a User System

This section explains how to build a user system.

■ Build a user system

Build the system on the ARM Workbench IDE. For details on how to build it, see "ARM Workbench IDE User Manual".

When the sample project included with µT-REALOS is built, "smpsys.axf" is created in the same directory as that the sample project exists.

APPENDIX

The appendix explains error messages of the configurator.

APPENDIX A Error Messages of the Configurator

Appendix A explains the categorization, display format, and meaning of error messages output during configuration.

■ Error Message Categorization of the Configurator

Error messages output by the configurator on execution of configuration are categorized by importance into the following three levels.

- Warning message

  Warning messages are less serious than the error messages described next, and the output results can be used almost without problems.

  Occasionally, a process different from what the user intended may be performed.

  Determine whether the output results are usable after checking the message contents.
- Error message

  The process is continued. However, the configuration is not performed. It is necessary to eliminate the factors causing the error and perform the execution again.

  This error mainly occurs while reading a file.
- Fatal error message

  An error indicating that the process cannot be continued. Such an error may occur due to problems in the execution environment as well as wrong specification by the user.

In addition, there are messages that are output by the compiler, assembler, or linker executed inside the configurator. For messages output by the compiler, assembler, or linker, see the corresponding manual.

■ Display Format of Configurator Error Messages

Error messages are output in the following formats:

```
*** File name(line number)XnnnnT:Message text(Assist message)
```

Section	Description
File name (Line number)	Configuration file name and line number where the error occurred. Output when error occurred while reading the configuration file.
X	Error level is expressed using one of the following three characters. W.... Warning message E .... Error message F .... Fatal error message
nnnn	Error number The error number and error level are associated as follows: 1000 to 1999 ..... W 4000 to 4999 ..... E 9000 to 9999 ..... F
T	Tool identification is expressed using the following character. M.... Configurator
Message text	Error message text
Assist message	More detailed information on the error. The symbol name indicating the error occurrence is output. It may be output to the error message body.

Note:

An error may occur at the complier, assembler, or linker launched by the configurator. For details of an error in such a case, see the corresponding manual.

■ Warning Messages

W1130M	Multiple definition (definition name)

The definition output in the definition name was duplicated.

This definition was overwritten by the definition specified later.

When a number is output in the definition name, the definition was overwritten by the definition specified later, using the ID indicated by the number.

W1401M	Not found maximum area definition (definition name)

Maximum area definition name output by the definition name does not exist.

When this error occurs, the maximum size is assigned automatically.

W1405M	EIT vector No. number is system reserve

As the interrupt number specified by number is system reserved, it cannot be used.

This error message is output when the interrupt number of an interrupt handler defined in "DEF_INH" is system reserved.

■ Error Messages

E4024M	Illegal character (parameter)

Characters that cannot be used in parameter output by parameter are contained.

This error occurs when characters are specified in parameter requiring numbers, or when numbers are specified in Parameter requiring labels.

E4026M	Specified value is out of range (parameter)

The value output in parameter is out of range that can be specified.

This error occurs when a value exceeding 32767 was specified in object ID.

E4110M	Unknown API name (character string)

Cannot use the definition output in the character string.

This error occurs when unsupported API name is described.

E4111M	Too long line (MAX value)

Description is not available when the line length exceeds the length output in the value.

Limit the description to the length output in the value.

E4112M	Illegal parameter expression

Parameter expression is illegal.

This error message is output when the description syntax or the definition method of API is illegal.

E4120M	Parameter is too long

The parameter length output in Parameter is too long.

This error occurs when a symbol is described with a length exceeding its specification.

E4121M	Too many definition name (MAX value)

Definition output in definition name exceeds the number output in the value.

This error occurs if an attempt is made to define more than standard API.

E4123M	Too many parameters (parameter)

Parameter beyond those output at parameter are unnecessary.

E4125M	Short of parameter

The parameters of the definition name are inadequate.

E4130M	Multiple definition (definition name)

Definition that cannot be duplicated was duplicated and defined.

This error occurs if ID of API is duplicated.

E4131M	Parameter not defined (parameter)

Parameters that cannot be omitted were omitted.

The parameter output in the parameter cannot be omitted.

E4132M	Illegal parameter (parameter)

Parameter that cannot be specified was specified.

This error occurs mainly when a string that cannot be selected in the selection item is specified.

E4133M	Symbol is already defined (symbol name)

A symbol that has already been defined was redefined.

This error occurs mainly when the task or event flag names, specified by API are duplicated.

E4136M	Illegal size or address (value)

The specified size or address is not correct.

E4142M	Device open count is bigger than semaphore count (MAX value)

Set the value of device open count or more to the value of the maximum semaphore count. Increase the value of the maximum semaphore count.

E4402M	API ID exceed maximum area definition (parameter)

More APIs output by parameter were defined than the value defined by the maximum area.
This error occurs even when the API is defined with no maximum area defined.

■ Fatal Error Messages

F9000M	Environment variable not found (environment variable name)

The environment variable output in environment variable name is not defined.

F9001M	Insufficient memory

Insufficient memory for program execution.

F9002M	Not configurated

Configuration was not performed.

This error occurs when execution is interrupted due to an error during configuration.

F9011M	Input file is not found (file name)

The specified input file is not found.

F9016M	Error read error (file name)

Reasons such as file without read privilege, hardware problems can be considered.

F9017M	File write error (file name)

Reasons such as file without write privilege, presence of the same directory or no free disk space can be considered.

F9022M	Unknown option name (option)

A parameter that cannot be specified was specified.

F9023M	Illegal option parameter (parameter)

The parameter output in parameter is illegally specified.

F9024M	Option parameter not specified (option)

The parameter is not specified in the option output in option.

F9030M	Missing input file name

The configuration file was not specified.

F9033M	Illegal file format (parameter)

This error occurs when format of files such as CPU information file is illegal.

F9405M	Initial task priority is higher than maximum task priority (MAX value)

This error occurs when the task priority of initializing process is higher than maximum task priority.

F9501M	Not found CPU information file

The CPU information file is not found at the specified location.

F9502M	Not found CPU information

This error occurs when the MB number specified by -cpu option has not been registered to the CPU information file.

Confirm the MB number specified by -cpu option.

F9801M	Definition name is not defined

The definition content output in the Definition name is not defined.

This error occurs when a definition or an option that cannot be omitted has not been specified.

F9805M	EIT vector No.number is system reserve

Cannot use the vector Number output in number is system reserved.

F9895M	Error in Compiler (file name)

Error occurred when compiling the file output in file name.

F9896M	Error in Librarian

Error occurred in the librarian.

F9897M	Error in Assembler (file name)

Error occurred when assembling the file output in file name.

F9899M	Tool name is not found

The compiler, assembler, or linker cannot be found from environment variable "PATH".

Define a path where the tool is contained in environment variable "PATH".

F9990M	File I/O error (file name, information)

Some error occurred during input/output of a file.

F9993M	Can not create directory (directory name)

Failed to create a directory output in directory name.

The reasons such as no directory writing privilege, presence of the same name directory name, no free disk space are considered.

F9994M	Can not create file (file name)

Failed to create a file output in file name.

The reasons such as no file writing privilege, presence of the same name directory name, no free disk space are considered.

F9995M	Can not close file (file name)

Failed to close a file output in file name.

The reasons such as no file writing privilege, presence of the same name directory name, no free disk space are considered.

F9996M	Can not open file (file name)

Failed to open a file output in file name.

The reasons such as no file writing privilege, presence of the same name directory name, no free disk space are considered.

F9999M	Internal error (identification information)

When this error occurs, contact sales representative immediately.

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FM3 Family

μT-Kernel Specification Compliant

μT-REALOS/M3 for RVDS

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